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COAL-TAR DISTILLATION.

BY PROF. SAMUEL P. SADTLER.

[*Concluded from Volume CXXI, page 110.*]

[*A Lecture delivered before the* FRANKLIN INSTITUTE *January 11, 1886.*]

The third case of the production of tar and ammonia as side-products, and of their recovery as residuals, is in connection with iron-blast furnace working, where raw coal is used as fuel. This has been recently attracting considerable attention among Scotch and English iron masters and to a very exhaustive article upon this subject by Mr. Wm. Jones, of the Langloan Iron Works,* where one of the processes to be mentioned is in operation, I am indebted for most of the facts to be stated. The coals used are the so-called Scotch splint coals, ultimate analyses of which show the following composition:

* Engineering, Oct. 16 and 23 and Nov. 6, 1885.

	Splint Coal, used at Gartsherrie.	Greenhill Splint Coal.	Rosehall Soft Coal, used at Langloan.	Hocking Valley Block Coal, (quoted before).
Carbon,	70·05	71·42	73·99	77·88
Hydrogen,	5·24	5·04	5·17	6·56
Oxygen,	12·08	10·40	10·52	10·57
Nitrogen,	1·36	1·46	1·32	1·51
Sulphur,	·75	·94	·54	·64
Ash,	3·80	2·24	4·10	2·84
Water,	6·72	8·50	4·36	. .
	100·00	100·00	100·00	100·00
Analyst,	Dr. Wallace.	Dr. Wallace.	Wm. Jones.	Lilienthal.

I have placed the ultimate analysis of the Hocking Valley block coal, quoted before, alongside of the Scotch coals for comparison. According to Jones, "Scotch splint coal contains on an average 40 per cent. of total volatile matters, of which 28 to 35 per cent. consists of tar, gas, etc., and they yield on an average 50 to 55 per cent. of fixed carbon. The conditions of the distillation in the blast furnace are rather different from ordinary retort distillation, or even coke-oven distillation." "We have the coal subjected in the first instance to a temperature of 600° to 700° F., and this temperature is a very gradually increasing one. Furthermore, the coal is being distilled in presence of oxide of iron and of gases rich in combined oxygen. Hence the enormous quantity of liquid products obtained from the coal, and the highly oxidized nature of the same." Mr. Jones states that, in his neighborhood, the temperature of the escaping gases is from 400° to 650° F., and the volume of gas per ton of coal averages 125,000 cubic feet at 60° F. "When we consider that this 125,000 cubic feet of gas leaves the furnace at 500° F., when it occupies a volume of over 230,000 cubic feet and that this gaseous volume is still further increased by 300 to 450 pounds weight of water per ton of coal, in the form of vapor at 500° F., arising principally from the oxygen of the coal and the water in the materials, and further that every ton of coal yields from 120 pounds to 220 pounds of tar, given off at this temperature partly as vapor and partly in a state of suspension, some idea is gained of the enormous gaseous volume per ton of coal issuing from the throat of a blast furnace, fed with raw coal."

The different principles and methods for the recovery of tar and ammonia from blast furnaces may be grouped as follows:

(I.) Methods depending on the condensation or cooling of the gas.

(*a.*) Alexander and McCosh process, or the Gartsherrie process.

(*b.*) Dempster process.

(*c.*) Henderson process.

(II.) Methods depending upon the use of acids without the cooling of the gas.

(*a.*) Neilson process, or Summerlee process.

(*b.*) Addie process, or Langloan process.

The Alexander and McCosh process is illustrated in *Fig. 5*. It depends upon the condensation or cooling of the gases, and the subsequent washing of the cold gases in towers or scrubbers. The gases from eight furnaces are collected in a main tube at the back seven feet in diameter over all. The gases are given a run of about 300 feet in this and a connecting tube, so as to allow them to deposit dust, and then enter the atmospheric condenser. This consists of 200 iron tubes 2½ feet in diameter and 40 feet in height, connected in pairs with a junction at the top and ranged in rows of ten. They are divided from each other by diaphragms in the usual way with a seven-inch seal. The whole apparatus stands on brick piers and the condensed products are run off to the storage pond by two seven-inch pipes provided with steam pipes to keep the thick tars as fluid as possible. Valves are placed at either end of this condenser. The temperature of the gases entering is from 300° to 400° Fahr., and they leave at 120° Fahr. The gases now enter the water condenser, consisting of a huge rectangular chamber, built of boiler plate. It is divided into seven chambers by iron diaphragms, open at the top and bottom, alternately to allow of the passage of the gases from one chamber to another. The water condenser is 45 feet in length, 18 feet in breadth and 45 feet in height, and is filled with three inch malleable iron tubes to the number of 2,700. These tubes are arranged in tiers and a current of water circulates through these tiers of tubes, the water travelling crosswise in an opposite direction to the gas. The water condenser stands on brick piers, and any condensed products are run off as before. Altogether about thirty gallons of water (natural

liquor) to the ton of coal are condensed from the gases, but the amount of tar condensed is comparatively small. The gases, now at a temperature of 60° to 70° Fahr., and under a suction of one and three-quarter inch water gauge enter the scrubber, which is 80

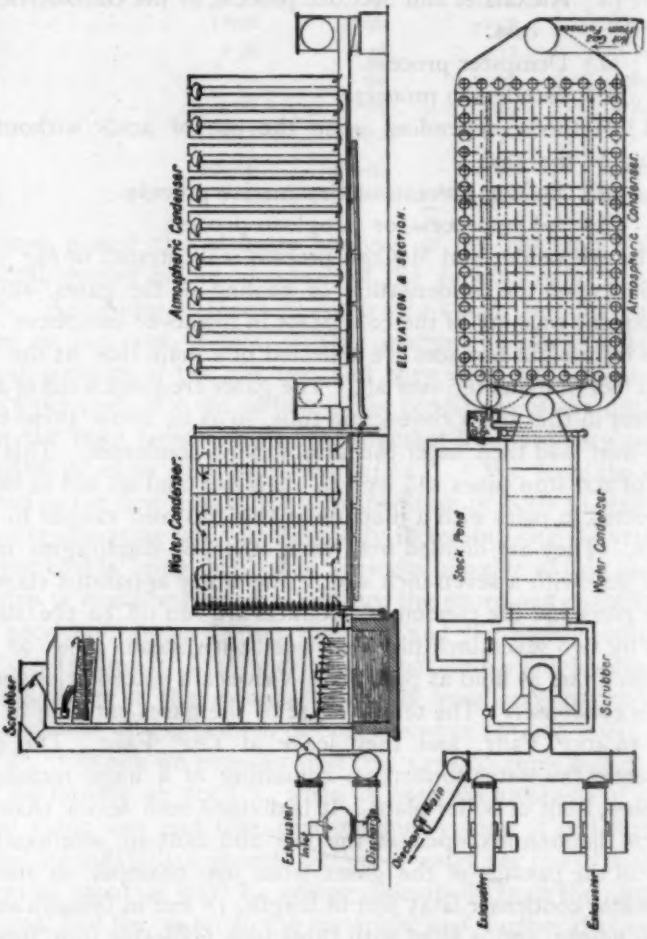
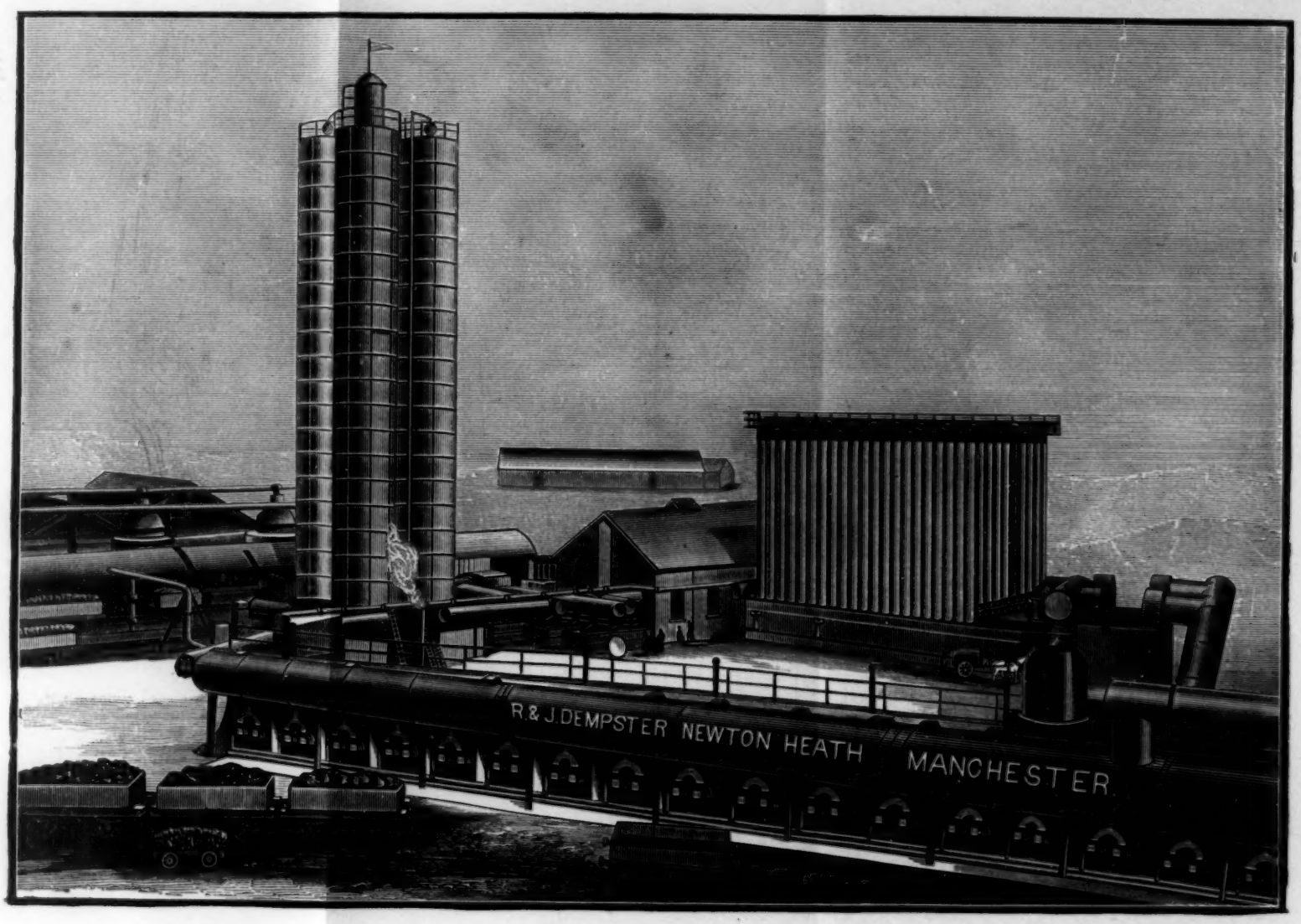


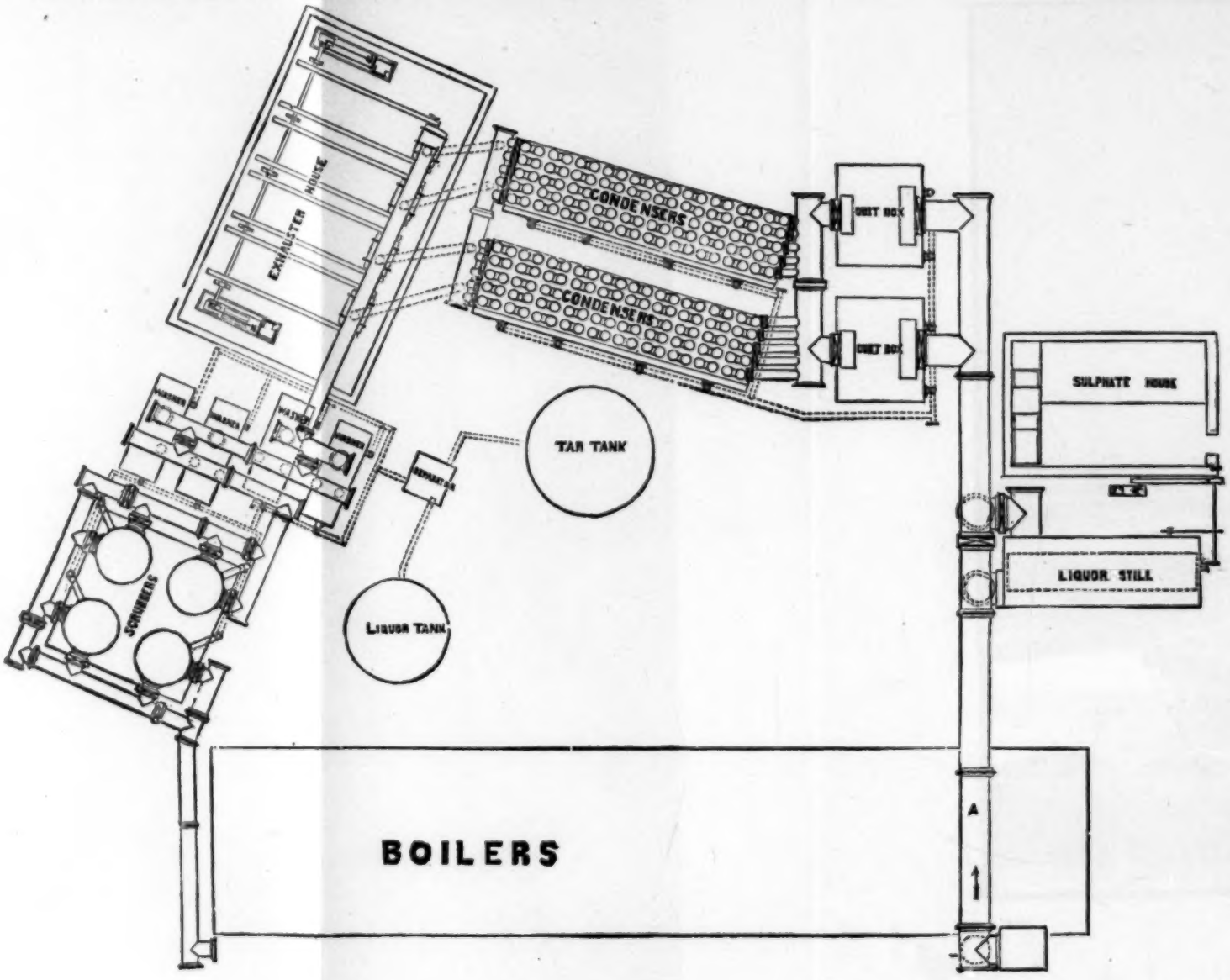
FIG. 5.

feet high and 25 feet square built of malleable iron plates three-eighths inch in thickness. It contains twenty-nine perforated diaphragms set at an angle. The scrubber is provided with explosion doors, a row of these being set opposite the end of each plate or diaphragm and serving for cleaning purposes as well.

(*Sadler. Fig. 6.*)



(Sadtler. Fig. 7.)



The tar falls into a brick tank where it is separated as much as possible from the liquor. The gases are taken off at the top of the scrubber by a five foot tube, and travel to a second scrubber similar to the one described, but smaller. The greater proportion of the tar is caught in the first scrubber, but even at the second there is a very considerable amount of tar obtained, showing the great difficulty of washing the tar out of the gases. The second scrubber also washes the last traces of the ammonia out of the gas. The make of sulphate of ammonia at Gartsherrie was when the article of Mr. Jones was written, about thirty tons per week, equal to twenty-two to twenty-three pounds of sulphate of ammonia to the ton of coal. The make of tar is forty gallons to the ton of coal, this being equal to sixteen gallons of boiled tar to the ton of coal.

The Dempster process is illustrated by *Figs. 6* and *7*, of which the first gives a general view and the second a plan view. The gases are conveyed first to the ammonia still and the flues of this still are made three times the size of the other pipes. This is to cause the gases to flow slowly round the still and by reducing the speed to allow the dust to fall to the bottom of the flue. The temperature of the gases being much higher than the boiling point, the nitrogen from the liquor is driven off without any expense for fuel. As the still is large enough to hold about twenty-four hours' make of liquor, the liquor is twenty-four hours under the influence of the heat, and all nitrogen is driven off. The gases then flow on to what are termed dust boxes, which are to arrest the remaining dust that may have passed the flues of the ammonia still, but they are really washers, and most of the tar is given off in the water here. The gases at the outlet of the dust boxes are very much reduced in temperature and are then brought down to the temperature of the atmosphere by two pipe condensers. These consists of 100 wrought iron pipes, 40 feet long and 20 inches in diameter. The gases are then drawn through the exhausters which consist of four of Roots blowers driven by a pair of horizontal engines. Following the exhausters come four washers which are to take out the last traces of tar before the gas gets to the scrubbers. The four round scrubbers are 100 feet high and 12 feet in diameter and are filled with about 300 tons of wood boards and on the top of each of the first three scrubbers is an apparatus for distributing the

liquor over the boards. The last one has only clean water pumped through it. The gas then passes on to the boilers.

The third, or Henderson process is illustrated in *Fig. 8*. Our

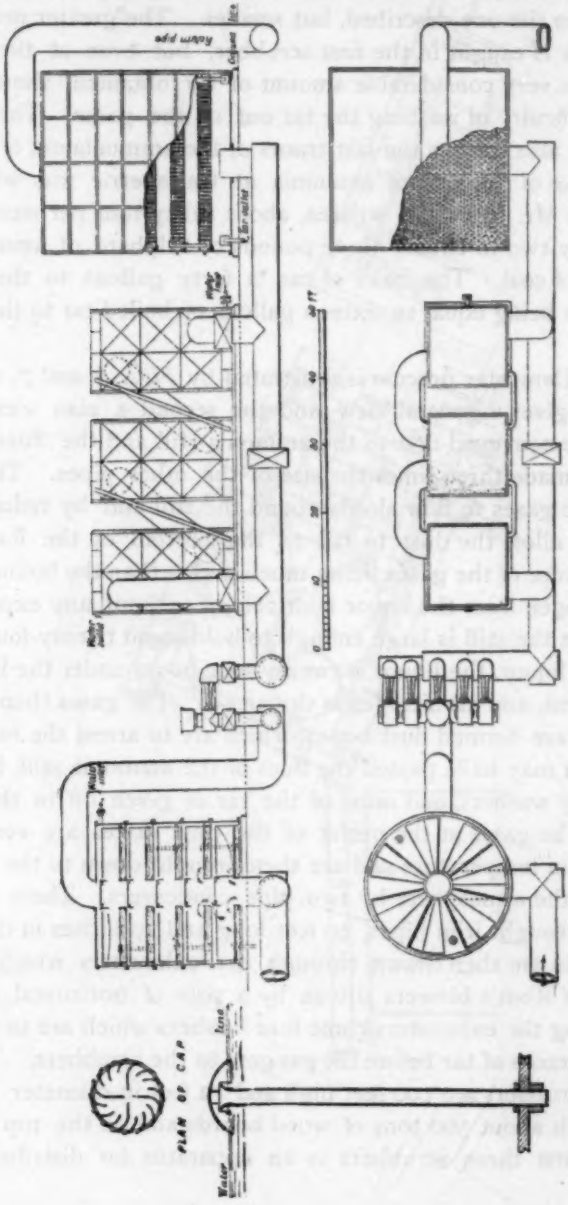


FIG. 8.

space will not allow of a detailed description of it. It includes (*a*) primary washer and cooler, (*b*) steam-jet exhauster, (*c*) slow speed water condenser, (*d*) a washer scrubber. A detailed description will be found in Mr. William Jones' article (*loc. cit.*).

The two remaining processes referred to, viz., the Neilson, or Summerlee process and the Addie or Langloan process both depend upon the absorption or fixing of the ammonia by acids combined with condensation or washing out of the tarry vapors. In the Neilson process figured in *Fig. 9*, this absorption

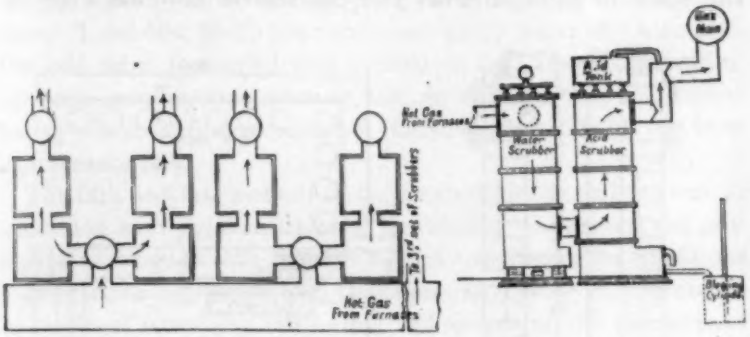


FIG. 9.

of the ammonia of the gases is effected by means of dilute sulphuric acid. A detailed description is given in Mr. Jones' article (*loc. cit.*). At the time of the writing of the article, the gases of two furnaces with about one-fourth of the gas from another were being handled and the make of sulphate of ammonia was from twelve to fourteen tons per week. In the Addie or Langloan process, sulphurous acid gas, made by burning "brasses" or sulphurous ironstone, is passed among the furnace gases in sufficient amount to combine with the ammonia and the gaseous mixture is subsequently washed in towers or scrubbers. It is illustrated in *Fig. 10*. In the apparatus as at present worked, the tar is not completely extracted. Mr. Jones (*loc. cit.*) states that, after passing through the apparatus, the gas is deprived of its ammonia but retains about forty per cent. of the tar which it originally contained. It is then distributed off to the heaters, boilers, etc., where it burns in the most satisfactory manner. The ammoniacal liquor obtained contains hyposulphite, acid sulphite and sulphate of ammonia. It is distilled with lime in ammonia stills like gas liquor and the ammonia freed and all con-

verted into sulphate. Plant is being erected at the Langloan works for the more thorough washing of the tars.

These blast-furnace tars contain no practicable amount of aromatic hydrocarbons and are free from anthracene. They are low temperature tars. The tars produced in the condensation methods contain from 30 to 42 per cent. of oil, while the tar from the hot washing processes contains from 20 to 25 per cent. of oil. The creosote oil from the Gartsherrie Works has a specific gravity of ·960 to ·980, and contains from 20 to 35 per cent. of phenols. The spirit or light oil from the Gartsherrie tars has a specific

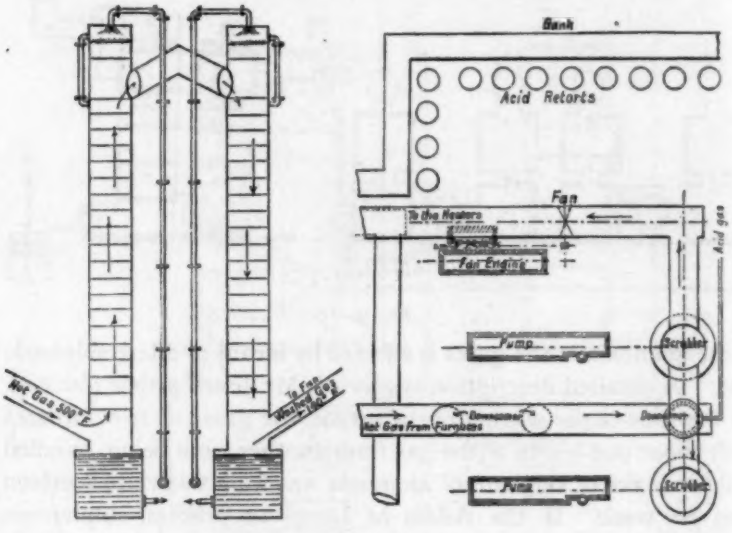


FIG. 10.

gravity of ·900 to ·910, and contains 15 to 20 per cent. of phenols Watson Smith obtains 23·1 per cent. of phenols from this variety of blast-furnace tar, as compared with about eight per cent. from Jameson coke tar, and 9 to 10 per cent. from gas retort coal-tar oil.

The fourth method of tar production was in connection with what are called "gas producers," of which a great number of forms, besides the well-known Siemens' producer, are known and used. In case the generators are fed with raw coal, we have, in addition to the formation of generator gas, a tar and ammonia production. This, it is true, is generally neglected, but it has in a few cases

been collected and some examination has been made of these residuals. Thus, the tar from the Sutherland gas producers, an English form of generator, has been chemically studied by Dr. Watson Smith. He found that its specific gravity was 1·085, being, unlike blast-furnace tar and the Jameson coke-oven tar oils, heavier than water, though only slightly. It is somewhat of the appearance and consistency of ordinary or gas retort coal-tar, but smells differently. It seems to be destitute of naphthas or spirit, which in some degree accounts for its higher specific gravity. The first distillation yielded the following percentages by weight of tar taken: Total oils, 36·9; coke obtained, 30·5; water and loss, 32·6. The oils were redistilled and yielded as final results lubricating oils, scale paraffin, some phenols, but no anthracene. The higher boiling oils show fluorescence, but not so much as similar oils from blast furnace tars.

The fifth and last method of tar production referred to, was in connection with the distillation of petroleum residues and the production of oil gas. We have already, in speaking of the conditions of destructive distillation, and the causes modifying it, referred to the results of Atterberg and Letny, and spoken of the character of the tar produced. In the case of Letny's experiments, in particular, we had petroleum residues destructively distilled with the production of tar, equal in amount to about forty per cent. of the oil taken.

Of oil gas methods, many have been brought forward, both in this country and abroad, but very little attention has been given to the liquid side-products of the distillation until recently. It is true that a thin liquid has been observed to condense in the holders where this oil gas is stored, especially when under some pressure. This was known to contain benzene and toluene. I had a sample of this light naphtha, as it was called, given me five or six years ago, taken here in this city from the drips of the reservoirs which supplied the oil gas for railway cars. But the thick tar formed in the processes of oil gas distillation has not been examined until recently. Prof. Henry E. Armstrong, of London, has examined two of these oil gas processes, the Pintsch and the Keith systems.

In the Pintsch system (*Fig. 11*), two cast iron D-shaped retorts are set one above the other, as shown in the figure, the largest size

in use being 6 feet 2 inches to 6 feet 4 inches long, 10 inches wide and 9¾ inches deep; the oil is run into the upper retort at one end, falling upon an iron tray which is loosely fitted into the

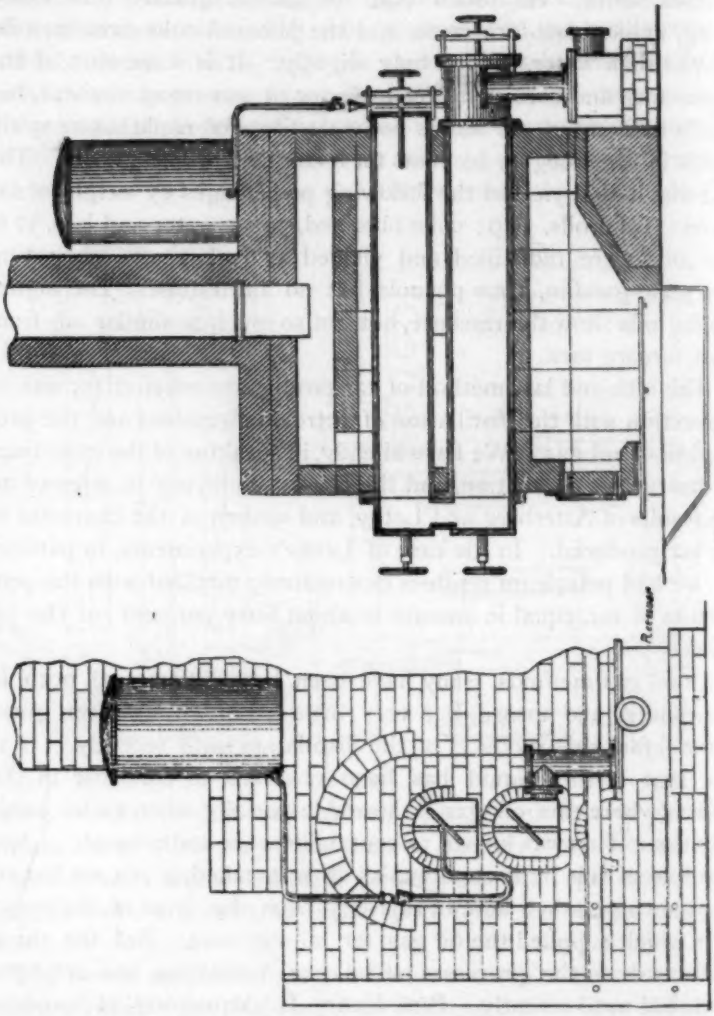


FIG. 11.

retort, and to complete the decomposition the vapors are passed into the second lower retort. The temperature at which the retorts are worked is very high—a bright cherry red. The oil may be run in at the rate of about twelve and a-half gallons per

hour. About eighty feet of gas per gallon of oil is reckoned a good yield.

The arrangement of the Keith plant will be obvious on inspec-

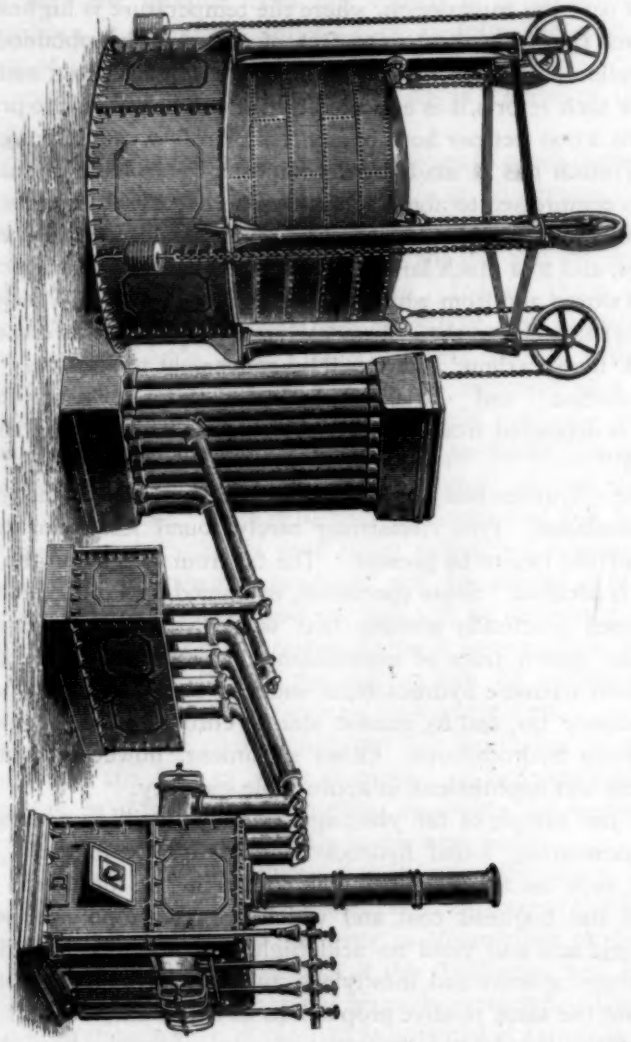


Fig. 12.

tion of *Fig. 12*. The retort is of peculiar form, being somewhat constricted in the middle. The largest size retort is 6 feet long, 5 inches broad, and 10 inches deep at the end; although shallow

in the middle, it is proportionally broader, so that the sectional area is the same as at the end. The oil is caused to flow down an inclined trough, not shown in the figure, so that it strikes the retort near the constriction, where the temperature is highest. It is stated that from 100 to 150 feet of gas may be obtained from one gallon of oil, according to the quality of the latter, and with twelve such retorts, it is expected that it will be possible to produce at least 2,000 feet per hour of not less than fifty candle-power gas.

"Pintsch gas is made by decomposing petroleum or shale oil and is compressed to about ten atmospheres; during compression, liquid is deposited in a chamber immediately attached to the pumps, and to a much larger extent in the reservoir in which the gas is stored and from which it is delivered into the iron recipients (drums) attached to the railway carriages; this liquid is commonly called 'hydrocarbon,' and it will be convenient to speak of 'pump hydrocarbon' and 'reservoir hydrocarbon.' A good deal of 'tar' is deposited from the gas prior to its collection in the gas holder."

The "hydrocarbon," as said before, contains benzene and toluene in abundance. Prof. Armstrong rarely found less than 50 per cent. of the two to be present. The tar from oil gas on the other hand is peculiar. Some specimens, examined by Prof. Armstrong, contained practically nothing that would volatilize in steam, and but the merest trace of naphthalene. It appeared to be all but free from aromatic hydrocarbons, such as occur in large quantity in ordinary tar, and to consist almost entirely of undecomposed petroleum hydrocarbons. Other specimens, however, contained benzene and naphthalene in appreciable quantity.

In the sample of tar yielding a fraction distilling with steam, Prof. Armstrong found hydrocarbons, apparently of the C_nH_{2n-2} series, such as Schorlemmer discovered in the light oils from cannel and boghead coal, and which are readily polymerised by sulphuric acid and yield no acid higher than acetic on oxidation. The three xylenes and mesitylene and pseudocumene are present in about the same relative proportions as in ordinary coal-tar; but, in addition, the oil-gas tar contains one—probably two—higher members of the benzene series. Naphthalene may be separated from the tar, and aromatic hydrocarbons of higher boiling point than naphthalene have also been obtained in small quantities. A

certain, though relatively small amount of a complex mixture of saturated hydrocarbons has also been separated from the tar; the quantity of material was quite small, but the author is inclined to believe that the mixture does not consist of paraffine, but of hydrocarbons of the C_nH_{2n} series—such as form the chief constituents of the Russian petroleum.

No examination has been made, as far as I know, of the tar from the Keith oil-gas manufacture.

We have thus pointed out how, in numerous other cases than in the process of manufacturing coal gas from bituminous coal, is it possible and even profitable to collect the tar and ammonia, which are formed at the same time as the gas and the coke as products of the destructive distillation. Indeed, there is no reason why these valuable materials should be lost sight of and despised as "residuals." As Prof. Armstrong has well said, "the time must come when coal-tar will not be regarded as a mere bye-product, and when attention will be paid, not only to the manufacture of gas, but also of coke and of *particular constituents* of coal-tar; when, in short, the materials latent in coal will be progressively utilized. It may be that then, the coal will first be coked, the oil which distils over being carefully condensed, and that the 'weak gas' thereby produced will be utilized as fuel; at the same time the ammonia and sulphur will be recovered. The paraffin, and whatever of immediate value it may contain, having been separated from the oil, the residue will be utilized in the production of oil gas and of benzene, anthracene," etc.

The possibilities of gaseous fuel are just beginning to attract attention and the uses of gases composed of hydrocarbons like natural gas, or of hydrogen and carbon monoxide like regenerator gases will probably extend greatly in the near future.

In presenting the possibilities of destructive distillation, I have looked almost exclusively at the amount and character of the tar produced. Much might be said, however, as to ammonia production, how it is affected by the conditions of the distillation and how it may be increased in amount and be properly extracted. That only a fraction of the nitrogen of the coal is obtained as ammonia in the aqueous distillate is universally conceded. Thus Mr. Wm. Foster (*Jour. Chem. Soc.*, London, 1883, pp. 105–110) finds that of the nitrogen of the coal, 14·50 per cent. is evolved as ammonia, 36·82

per cent. in the gas or tar, and 48·68 per cent. remain in the coke. Mr. George Beilby (*Jour. Soc. Chem. Ind.*, 1884, p. 216) states that when bituminous shales are distilled 17·0 per cent. of the nitrogen is found as ammonia in the watery distillate, 20·4 per cent. in the oil as alkaloidal tars, and 62·6 per cent. remain in the residue or coke. We have already shown that the temperature of distillation is one feature which affects the ammonia yield of any coal; high temperature destroying the ammonia first formed in the decomposition of the coal with the moisture present. If the distillation be pushed very slowly from low to high temperature by gradual stages, more ammonia can be gotten than when as in the gas retort process a very high temperature is used at once. Thus Beilby (*loc. cit.*) found that a slow distillation of this kind yielded instead of the result before quoted, 32·8 per cent. as ammonia in the watery distillate, 20·0 as alkaloids in the tar, and 45·7 per cent. in the coke.

But the development of the largest amount of ammonia from the nitrogen of a bituminous coal or shale seems to require the aid of steam acting upon the decomposing mineral or the coke as it is formed. Thus Mr. Beilby, using the same bituminous shales as yielded the results before quoted, (*loc. cit.*) by first distilling at a low red heat in an iron retort, and afterward subjecting the residual coke to the action of steam at a bright-red heat in a fire-clay retort, obtained of the nitrogen, as ammonia in the watery distillate 74·3 per cent., in the oil as alkaloidal tars 20·4 per cent., and remaining in the residue or coke 4·9 per cent. only.

Following on the same principle, Messrs. H. Simon and Watson Smith have patented a process (Eng. Pat., 4,871, Oct. 13, 1883,) for increasing the production of ammonia and its compounds during the process of making coke or gas. This they do by injecting into gas retorts, coke-ovens or gas producers, provided with arrangements for recovering by products steam along with hydrocarbons in a liquid or gaseous form. They claim that whilst the oxygen of the steam unites with the carbon, a portion of the hydrogen set free combines with the nitrogen of the partially decomposed coal forming ammonia, a portion also of the hydrogen unites with the sulphur of the fuel so that the quality of the coke is improved by the treatment.

With the present interest which is felt in the improvement of

our processes for treating coal and utilizing more fully its latent possibilities, we doubt not that much will be added to our knowledge of distillation methods and results in the near future.

THE DEVELOPMENT OF DYNAMIC ELECTRICITY.*

BY WILLIAM DENNIS MARKS,
Whitney Professor of Dynamical Engineering, University of Pennsylvania.

[*A Lecture delivered before the New York Academy of Science, December 25, 1885.*]

Electricity can, at our will, be converted into heat, light and motive-power. With all these capabilities, it lends itself in a wonderful way to the convenience of man, because of its ability to be led to the exact point at which we desire to use it, and can there be used at will in large or small quantities.

In short it possesses—

Facility of distribution;

Indefinitely great divisibility according to need; and

The ability to concentrate great power in a very small space.

I must limit myself, because of the brief time allotted, to the consideration of a small part of my subject, and even in this I will still further limit myself to the phenomena occurring on so considerable a scale as to be generally called engineering problems.

I will particularly call your attention to the conversion and reconversion of electrical energy into other forms of energy, in three ways:

(1.) The conversion of heat into electrical energy;

(2.) The conversion of electrical energy into light;

(3) The conversion of electrical energy into mechanical energy.

THE CONVERSION OF HEAT INTO ELECTRICAL POWER.

The direct conversion of heat into electrical energy, has already had a partially successful, but not economical, solution in Clamond's stoves.

According to Cabanellas, a Clamond's stove consisting of 6,000 elements, and burning twenty-two pounds of coke per hour, will give a current of seven ampères, and 218 volts difference of potential.

* From advance sheets of the Transactions. Vol. V, No. 3, 1885–6.

Cabanellas also states that the amount of light obtained was equal to about 560 standard English candles.

This would give us nearly twenty-six candles per pound of coke. As we shall presently see, this is a result much less economical of fuel than can be obtained by the use of an engine and dynamo, under very unfavorable circumstances. The liability to derangement and the first cost of Clamond's Pile have prevented it from becoming commercially successful.*

Those of you who are familiar with electrical terms, will pardon me if I devote a small portion of our time to the endeavor to make their meaning clear to those who have given little time or thought to them, but are familiar with purely mechanical ideas.

The ohm, volt, and ampère are the practical British Association units used by electricians.

The legal ohm is the resistance of a column of mercury one square millimetre in cross section, and 106 centimetres in length, at the temperature of melting ice.

Ohm's law is

$$\text{Intensity of current} = \frac{\text{Diff. of Potential}}{\text{Resistance}}, \text{ or } I = \frac{E}{R},$$

from which you at once see that the resistance equals the ratio between the electro-motive force lost in the circuit, and the intensity of the current.

This is a constant for any solid so long as its form and temperature are not changed.

The volt, and ampère are more difficult to define, and perhaps I can best make their meaning clear by making use of analogous hydraulic formulæ.

Understand me, this is only a case of analogy. I do not say that electricity is a fluid, nor would I like to say that there is a current of electricity, or that it flows one way or the othor.

The volt may be said to represent the pressure or head of the assumed current of electricity, and the ampère to represent the intensity or weight of the current passing in one second. Lord Rayleigh has carefully determined the weight of silver precipitated

* These elementary explanations were made at the request of the Secretary of the New York Academy of Science, who requested me to endeavor to make my lecture "of interest to the general public by simple explanations." [W. D. M.]

from a solution of nitrate of silver by one ampère. It is 0·06708 grammes per minute, or 4·0248 grammes per hour.

Referring to *Fig. 1*, if W equals the weight of water that passes the point A in a pipe, in one second, and h the loss of head, we have for the work done in one second, $W\,h$ foot pounds.

Again, if I represents the intensity of a current passing the point A in a second, and E the difference of potential in volts between B and A, we have for the work done in one second $I\,E$ volt-ampères, or watts. If we divide $W\ h$ by 550 foot pounds we obtain the horse-power.

In the case of the pipe, if it were level, the loss of work would be due to friction, and transformed into heat.

$$\text{Thus } h = \frac{v^2}{2g} \text{ and } W\,h = \frac{W\,v^2}{2g} = \frac{M\,v^2}{2}.$$

Joule has shown us by experiment that the heating of a wire conductor is proportional to $I^2\,R = I\,E = \frac{E^2}{K}$, or using the analogous hydraulic formula, the heating is, $W^2 \times \frac{h}{W} = W\,h = \frac{h^2}{\frac{h}{W}}$

Again, $\frac{I\,E}{9{\cdot}81}$ = work per second in kilogrammetres, but an English horse-power equals 76·04 kilogrammetres per second, and, therefore, one horse-power $= \frac{I\,E}{745{\cdot}9}$. Returning again to the ohm, we have $R = \frac{E}{I}$. That is, the resistance is the loss of electro-motive force per second and per unit of intensity which an electrical current experiences when passing along a conductor. If this conductor is the standard quick-silver column, $R = 1$ ohm.

In an analogous manner we would say of a horizontal pipe con-

veying water, that the resistance is the loss of head per pound and per second, when passing through the pipe.

The resistance of the various materials used as conductors for the electrical current has been repeatedly and carefully determined.

I trust I have established a clear and cordial understanding of the terms which I shall need to use.

By the electro-motive force in volts, I mean something similar to the head of water in feet; or its pressure in pounds.

By the intensity of a current in ampères, I mean something similar to weight of water passing in pounds per second.

By the resistance in ohms, I mean something similar to the loss of head of water per pound and per second.

The dynamo-electric machine is the newest, and the most perfect of machines for the transformation of energy from one form to another. Like the turbine, its efficiency has been proved so great as to preclude all hope of further increase of practical value. Its cost may be reduced by improved processes of the machine shop, we cannot do more.

One reason for this rapid perfecting lies in the apparent obscurity of electrical phenomena, which has had the effect of repelling all but subtle and acute minds from their study. The right end of the thread once seized by such minds, they have followed the clue with such rapidity and thoroughness of apprehension as to leave nothing more for us to accomplish.

The recent experiments of the FRANKLIN INSTITUTE upon the dynamos of Weston and Edison have set the seal of absolute measurement, with a great exactitude as we can hope to reach, upon the ability of these machines to transform mechanical work into electrical work.

Of the five dynamo-electric machines which successfully withstood the severe conditions of the code, Weston's mammoth incandescent lamp machine, of a rated capacity of 125 ampères and 160 volts, returned as an average of four tests, in the form of electrical energy $96\frac{56}{100}$ per cent. of the mechanical power used to drive it. $89\frac{37}{100}$ per cent. of the mechanical power was available as electrical energy in the external circuit.

Of the total mechanical power applied, about one per cent. was lost in friction of the armature shaft, and resistance of the air to its rapid revolution.

Two and one-half per cent. only remains to be accounted for, and was presumably lost in the form of heat and eddy currents.

Every precaution was taken to avoid results which would not appear in every-day use, and all of the machines were run under full load for ten hours before the measurements began, and so were at as high a temperature as would be reached in actual practice with the same atmospheric temperature. The performance of this particular machine only exceeded the least efficient the machines tested by two and one-tenth per cent. total efficiency.

These results show that this high efficiency is not extraordinary, but is and should be attained by all dynamo makers building similar types.

In the case of the Weston (7 M.) dynamo, already specified, the power applied was distributed as follows in the first full load test:

Friction and wind resistance of armature, . . .	·0106 total.
Electrical energy lost as heat in armature, . . .	·0559 "
" " " in creating field, ...	·0170 "
" " " in external circuit, . . .	·8992 "
Total of power accounted for, ...	·9827
Electrical energy lost in eddy currents, heat, and otherwise unaccounted for, ...	·0173
Total power as per dynamometer, ...	1·0000

This differs from the average already quoted, because slight variations of the conditions would cause any of the machines to vary somewhat in their percentages.

The greatest cause of uncertainty in experiments heretofore made upon the transformation of mechanical power, has been our lack of certainty of accuracy in the measurements of the mechanical power driving the machine. The dynamometer must sum up the whole power yielded to the dynamo with as great accuracy as is possible for all other measurements in part.

This dynamometer must be capable of being standardized by absolute measurement, and, after being standardized, the machines to be tested must be able to be attached to it or removed from it without altering the centres or adjustments of the dynamometer. It must be of great sensitiveness to small variations of load, while measuring large amounts of power with great steadiness.

All of these conditions were fulfilled by the dynamometer invented by Mr. Wm. P. Tatham, President of the FRANKLIN INSTITUTE. Its extreme capacity is 100 horse-power, and yet, while making 1,040 revolutions per minute, carrying a load of twenty-nine horse-power, it was possible to measure with certainty the difference of power required by an Edison voltmeter requiring two-tenths of a horse-power. It announced at once the making and breaking of the circuit of this voltmeter, measuring the work lost in it with accuracy. Still other tests showed its capability to promptly register small changes of power while carrying great loads, and proved that the slight and rapid jar of the parts, due to a high speed, increased its sensitiveness of measurement.

Finally, this dynamometer was calibrated by the agitation of water, heating something over five tons of water through 15·5° Centigrade, giving, as the mechanical equivalent of heat, 772·81 foot pounds per British unit of heat (see Report).

While less can be claimed in the way of originality of apparatus or methods used in the electrical measurements of these tests, I trust that an examination of the precautions will convince you of the extreme care taken to obtain correct results. (See "Competitive Tests of Dynamo Electric Machines," JOURNAL FRANKLIN INSTITUTE, Nov., 1885.)

The dynamo-electric machine has grown out of the fact that, if we move a dead wire in the field of another fixed wire, through which a current is passing, the dead wire will have a current generated in it whose electro-motive force is proportional to, (1), the intensity of the current in the fixed wire; (2), to the velocity of motion of the moving wire, and (3), to the acting length of the moving wire.

If I take a single wire, *Fig. 2*, and pass a current through it, its field will resemble a whirlpool of which the wire is the centre.

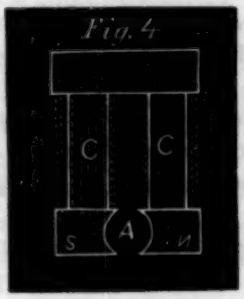
If I take two wires and place them a short distance apart, *Fig. 3*, and pass a current in the same direction through both, their

fields will combine to form an oval field, and any number of adjacent wires, with currents in the same direction, will do the same thing, forming a field of an intensity proportional to the number of wires and the intensity of the current in each. The field would, however, be of loose texture, so to say, and the lines of force far apart if the lines of force formed themselves around the wires in the air.

Iron, because of its great permeability to the lines of magnetic force, enables us to concentrate this field, and to place it, so to speak, where we desire to use it.

Pure, soft, wrought iron may be said to be 20,000 times more permeable than air.

Fig. 4



You will see from *Fig. 4* what I mean. The wrought-iron cores *C* afford the easiest path for the lines of force, and they therefore follow them until they reach the armature space *A*, between *N* and *S*, where they take their airy path across, because the lines of force must always close.

We see that we have thus managed to concentrate the lines of the field of a large number of coils in a small space *A*. In this space the wires of the armature are revolved so as to generate a current which is either alternating, or approximately continuous.

The details of armatures and winding of them, as well as of the commutators, will be found described at considerable length in the works on "Dynamo Electric Machinery," written by Dr. Schellen, or Prof. S. P. Thompson.

I do not think that there is anything written better calculated to give the novice a clear idea of the principles involved in a continuous current machine, than Pacinotti's own description of his

machine, which can be found in the translation of Schellen, by Dr. Keith, on page 209.

I have shown you how perfectly the dynamo converts mechanical into electrical power, and I will now have to confess to you how exceedingly imperfect and irregular are the present methods of transformation of heat into mechanical power. Engines and boilers are both built in entire disregard of the actual principles of thermo-dynamics, and there has been so little accurate knowledge of the practical laws which should govern their construction, that makers, in many instances, shelter their wretched designs and workmanship behind the impossibility of predetermining the proportions which will realize the greatest economy of heat.

My own researches have convinced me of the impossibility of using small cylinders with any degree of economy of steam, unless they are compounded so as to permit between eight and ten expansions.

In the case of non-condensing engines, the boiler pressure should be about 135 to 140 pounds by the gauge, and in the case of all engines the speed should be as high as is consistent with safety.

Much of this waste is due to initial condensation of the steam on entering the steam cylinder, which was perceived by Watt, and partially remedied by him.

The quantitative law of this condensation, and its influence upon the most economical expansions of steam, I have endeavored to formulate in a paper in the JOURNAL OF THE FRANKLIN INSTITUTE for March, 1884, and showed, in the same journal, August, 1880, how narrow were the limits of Marriotte's law for the profitable expansion of steam, even neglecting the initial condensation.

Taking matters as they are, the most economical engine used for the purpose of driving dynamos at the late Electrical Exhibition of the FRANKLIN INSTITUTE required about thirty pounds of steam at ninety to 100 pounds pressure, and the most economical boiler evaporated about eight pounds of water per pound of anthracite coal at the same pressures. That is, an indicated horse-power required three and three-fourths pounds of average anthracite.

It can be assumed, with close approximation to average correctness, that fifteen per cent. of the indicated horse-power is lost in

the most direct method of transmission of power from engine to dynamo.

So we can say that one utilizable electrical horse-power per hour may, in good practice, be obtained from

$$\frac{3{\cdot}75}{85} \times \frac{100}{90} = 4{\cdot}\frac{90}{100} \text{ pounds of coal,}$$

(such as is sold in the open market as chestnut anthracite), and neglect the loss of electrical energy in the conductors.

The carbon equivalent of the coal used was ninety-one per cent. by weight.

Assuming 14,500 British units as the heat per pound of carbon, we have

$$4{\cdot}90 \times {\cdot}91 \times 14{,}500 = 64{,}655 \text{ British units of heat.}$$

Assuming the mechanical equivalent of one British unit as 774·1 foot pounds, we have very nearly 2,558 British units for one horse-power per hour. Dividing the last by the first we find that nearly four per cent. of the power latent in the coal appears as electrical power in the circuit. Ninety-six per cent. of our potential energy is lost; principally in the steam engine.

These facts, taken from the labors of many impartial and skilful workers in scientific research do not correspond with the alluring statements frequently set before us, but I believe them reliable and practical.

The broad lesson to be drawn from them is that we do not obtain one–twenty-fifth of the power in coal in the form of electricity; and that twenty-four–twenty-fifths remain to be obtained by the discoverer of an economical method of direct conversion of heat into electricity.

When the direct method of conversion of heat into electrical energy yields a larger percentage of the power in coal than the indirect method which I have just described, at the same cost, then will the dynamo supplant the steam engine. Until then it must remain what it is—a distributor of power for the steam engine, or other mechanical motor.

THE CONVERSION OF ELECTRICAL POWER INTO LIGHT.

There are at present in use two methods of converting electrical power into light. The first and apparently the most economical is by means of the voltaic arc between carbon points, the second, by means of the incandescence of a carbon filament in a vacuum.

The first method is open to severe criticism, save on the point of economy, and for lighting large spaces.

The briefest look at the intense spot of light formed by the arc between the points of carbon causes a painful and persistent image on the eye. The light has a vicious way of hissing, which becomes unendurable to sensitive nerves, and it varies the monotony of this noise by sudden jumps and flickers. Its ghastly effects are due to its bluish color and the deep, sharply-defined shadows.

In some cases the arc has a way of rotating around the axis of the carbons, which also causes variations of the intensity of the light in different directions.

Opal glass-globes, which cut off something more than one-half the light, are required to make the light tolerable; and as for the lamp itself, I do not think the greatest skill and taste of designers have yet rendered it ornamental when not lighted.

As a rule, the arc light is most intense when viewed at an angle of 45° from the vertical, and for this reason it is usually used for lighting open spaces from a considerable height I will assume its power as an average of the illumination at 30°, 45° and 60° from the vertical.

From the report on Electric Lamps of the FRANKLIN INSTITUTE, June, 1885, I take the following data:

Machine.	Angle with Vertical.	Candles.	Candles per El. H. P.	Average Candles per El. H. P.
Arago Disc,	30°	645	783	
	45°	583	708	
	60°	465	565	685
Ball,	30	182	421	
	45	485	1,123	
	60	520	1,204	916
Brush (1,200 c. p.),	30	355	762	
	45	613	1,316	
	60	537	1,152	1,076
Brush (2,000 c. p.),	30	1,200	1,529	
	45	1,373	1,750	
	60	1,082	1,379	1,553
Diehl,	30	887	1,176	
	45	830	1,101	
	60	725	961	1,079
Richter,	30	603	743	
	45	894	1,101	
	60	960	1,183	1,009
Van Depoele, 20 lights,	30	670	780	
	45	1,377	1,604	
	60	1,060	1,235	1,206
Van Depoele, 60 lights,	30	500	612	
	45	1,162	1,423	
	60	900	1,101	1,045
Western Electric,	30	75	121	
	45	266	431	
	60	355	575	376
	Average,			994

The average candles per electrical horse-power obtained from measurements upon the Arago disc, Ball, Brush, Diehl, Richter, Van Depoele, and Western electric machines was 994.

The efficiency of these arc-light machines was not obtained, but we are justified in assuming that seventy per cent. of the absorbed power should reappear as electrical power in the circuit, neglecting its losses.

That is, $\frac{3{\cdot}75}{{\cdot}85 \times {\cdot}70} = 6{\cdot}3$ pounds of ordinary anthracite coal per electrical horse-power per hour.

$$\frac{994}{6{\cdot}3} = 158 \text{ candles.}$$

If we divide the candles per electrical horse-power by the weight of coal required to produce them, we find in the arc system that we obtain 158 candles per pound of coal for the naked light, and something less than seventy-five candles if ground glass or opal globes are used, and the light seen from the most favorable position.

Very different from the arc light is the incandescent. Its light is so soft that we do not realize its brilliancy until we submit it to measurement. It gives out no products of combustion to poison our air; it shows colors truly. A delicate hair of carbon, sealed within a vacuum by walls of glass, glitters and glows until at almost limpid incandescence it gives us a steady, clear light, colorless as daylight.

If you will take a book and hold it from one to two yards away from a sixteen-candle light, you will find it sufficiently diffused to read with comfort.

Now all know that the intensity of illumination varies inversely as the square of the distance. Therefore, roughly estimating a shaded arc light at 500 candles, the same book would have to be held somewhere between five and one-half and eleven yards away from it to be read with equal comfort, assuming the light to be steady. We can then say that a sixteen-candle incandescent light will illuminate a circle of twelve and one-half square yards area, and that a shaded arc light giving 500 candles out of 994 will illuminate a circle of 400 square yards area, or thirty-two times as great. That is to say, about thirty-two sixteen-candle lamps would supply an equal illumination with a vastly better distribution of light for the use of the eyes.

We can, therefore, say that 500 candle-power from incandescent lamps will far more than replace 1,000 candle-power from the arc light, under the conditions, of actual usage.

We can safely say that, for all purposes save that of obtaining light to dispel darkness, the incandescent light is twice as valuable, light for light, as the arc light, and, therefore, should be multiplied by two when compared with it.

The objections most vehemently urged against incandescent lamps have been their short life and lack of economy; this is not true of them in all cases.

The first public test of the life of incandescent lamps was made by the FRANKLIN INSTITUTE in the early months of 1885 (JOURNAL OF THE FRANKLIN INSTITUTE, September, 1885.) The record of these tests is given in a pamphlet of some 130 pages, and with a detail which renders it impossible, in our limited time, to do more than gather from its averages such general lessons as we may learn.

From the efficiency test, which was preliminary to the prolonged duration test, we find that 194·1 spherical candles were realized per electrical horse-power.

	Spher. Candles.
Edison's 97 volt lamps—per El. H. P.,	169·2
Stanley's 96 " " " "	189·1
" 44 " " " "	216·1
Woodhouse & Rawson's 55 volt lamps—per El. H. P.,	209·0
" " " 55 " " " "	210·8
White's 50 volt lamps—per El. H. P.	182·6
Weston's 110½ volt lamps—per El. H. P.,	209·8
" 70 " " " "	166·3
Average, " "	194·1

The committee was forced by the different forms of carbon filament used to take the illuminating power of the lamps from all points, and to call the mean the spherical intensity of illumination. This procedure perhaps gives a better idea of the practical value of the incandescent lamp, because it is customary to place these lamps in any position that convenience may dictate.

I have already, I trust, convinced you that the incandescent lamp, by reason of its smaller quantity of light and better distribution, is worth at least twice as much as the arc light. I have also told you that one electrical horse-power costs with Weston's incandescent dynamo-electric machine, about 4·9 pounds of ordinary anthracite. Therefore, one pound of coal will give about forty candles by the incandescent lamp, and this is equivalent to eighty, and probably many more, candles by the arc light, whenever we have to use our eyes for any purpose save guarding our footsteps.

You will recall that under assumptions most favorable to the arc light, I showed you that we probably do not get more than seventy-five candles per pound of anthracite from the shaded arc

light. Had the Committee on Arc Lights obtained the spherical intensity of illumination of these lamps, their showing could have been made much less favorable than the one given. The present method of arc lighting must ultimately give way before the incandescent light, save for large spaces not requiring a close use of the eyes.

The low potential and larger current of the incandescent dynamos render necessary a lower resistance in the conductors, and so the cost of wiring for incandescent lamps is much greater, because of the increased weight of copper wire demanded to convey the current without too great a loss in the form of heat. This is the pecuniary obstacle, and about the only one that prevents the entire disappearance of the arc light before the incandescent light. Could an incandescent lamp be made of sufficiently high resistance to enable the use of high potentials, the last objection to the system would vanish. Who knows but that in a few days we may hear of its accomplishment?

The Edison ninety-seven volt lamps in this test, outlived all the others, demanded the least weight of conductors, and was thirteen per cent. less economical of power. It was the only lamp in the test that justified a claim to 1,000 hours of life.

Nineteen out of twenty lamps entered by this company survived a continuous test of 1,006 hours.

Mr. Weston entered a tamidine carbon lamp, intended to be used with 110½ volts, but imperfection of manufacture subsequently led him to pronounce them worthless.

The more successful lamps were found to undergo a process of gradual degradation which is attributable to two causes, an increase of the resistance of the carbon filament, and a deposit of carbon upon the interior of the glass of the lamp.

The discoloration of the various lamps was carefully compared after their life had ceased, and was remarkably deep in the case of the Woodhouse & Rawson, and the Stanley fourty-four volt lamps. Indeed, it would seem as if this discoloration was in some wise proportional to the economy of the lamp, as these two were the most economical of the makes of lamps entered.

A lamp may live a long time and yet be of little value for the purpose of giving light, because of this degradation. If you will take a lamp which has been used some time, and lay it upon a

white handkerchief, the gray coloring matter on the globe will be brought out quite distinctly.

Thus we see that great length of life with little usefulness may be attained by lamps. Indeed, the Edison lamps, which outlasted all others, had lost thirty-six per cent. of their illuminating power at the end of 1,006 hours.

Before turning to my last head, I will remind you that the direct conversion of heat into electrical energy by Clamond's stoves only produced twenty-six candle-power per pound of coke, as against forty candles per pound of anthracite in the usual way with incandescent lamps.

It will be a surprise to me should not the direct conversion of heat into electrical power prove to have quite as many difficulties, and as narrow limits as the conversion of heat into mechanical power by means of the steam engine.

THE CONVERSION OF ELECTRICAL POWER INTO MECHANICAL POWER.

The problem which just now is demanding of electricians their most earnest effort, is the transmission of work by means of electricity. This effort will be repaid by the utilization of otherwise inaccessible water-powers; and the problems of locomotion will have their simplest and least objectionable solution when it is an accomplished fact.

Marcel Deprez has recently transmitted sixty horse-power from Creil to Paris with a mechanical efficiency of fifty-three per cent.

The expense attendant upon an experiment of this magnitude has been very great, but the scientific possibility once proved, we can rely upon the progress of manufactures to reduce this expense, and to define the limits within which power can be economically delivered.

Seventy-five per cent. of the indicated power of the engine is not an overestimate of the power required to move the cable alone for our cable cars on a road of two or three miles length, but it would at once condemn an electric railway, which should be made to yield a practical efficiency of over fifty per cent.

Before discussing the details of the transmission of power, I will, with the aid of our previously used hypothetical fluid and

pipe, and with two pumps to represent the dynamo and motor, endeavor to make clear to you the laws controlling the transmission of power by electricity.

I must again remind you of the fact that I disclaim any knowledge of the real nature of electricity, and that I am reasoning from analogy alone.

Assume two pumps, *Fig. 5*, *A* and *B*, connected by a closed line of pipe so that the fluid must be pumped round a closed circuit. Let the pump *A* be driven by means of any external power. Let the pump *B* be reversed and acting as a motor. Let each of these pumps have a vertical stand-pipe projecting from its top, which will show the head *E* or *e* resulting from its action. The pump *A*

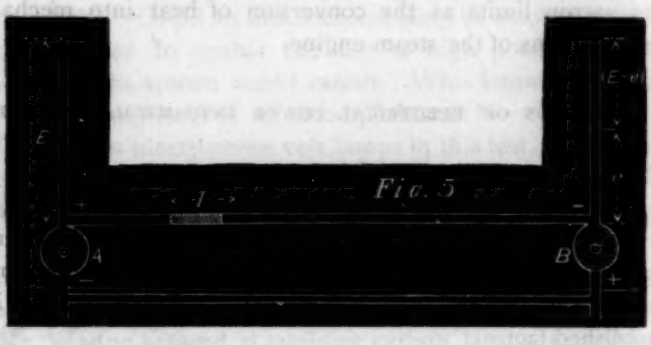


Fig. 5

acts under the law that its head *E* is proportional to the speed at which it is driven. The motor *B* acts under a similar law that its counterhead *e* is proportional to the speed at which it is allowed to run. The weight of fluid, per second, passing through the conduit, is directly proportional to the difference of these heads, and, inversely, to the resistance.

Let *I* equal the weight of fluid passing along the pipe each second.

The fluid passing along the pipes between *A* and *B*, and through the pumps, will lose, each second, a certain amount of head per unit of weight, because of the resistances.

Let *R* equal this resistance. Then we can say:

The weight of fluid per second is then directly proportional to the effective head, and inversely proportional to the resistance. This is Ohm's law, which, for electricity, is: *The intensity of the current is*

directly proportional to the difference of potential, and inversely as the resistance.

The loss of power, per second, in friction in the pipes, is the loss of head multiplied by the weight per second. This is Joule's law for loss in heat for electricity:

$$E\,I = \frac{E\,(E-e)}{R}, \quad R\,I^2 = \frac{(E-e)^2}{R}, \quad e\,I = \frac{e\,[E-e]}{R}$$

Work per second of pump A = Head $\times$ wt. per second.

" " " " " " $= E\,I = \frac{E\,(E-e)}{R}$

" " " lost in pipe $A\,B = I^2\,R = \frac{(E-e)^2}{R}$

R = head lost per unit of weight per second.

$I = \frac{E-e}{R}$ Weight per second $= \left\{ \frac{\text{diff. head}}{\text{head lost per unit of wt. per second.}} \right\}$ (Ohm's law.)

Work lost per second $= I\,(E-e) = \frac{(E-e)^2}{R} = I^2\,R$

(Joule's law).

Work per second of motor B = head $\times$ wt. per second.

" " " " " " $= e\,I = \frac{e(E-e)}{R}$

$$\text{Theoretical Efficiency} = \xi = \frac{e}{E}$$

Work of motor B per second a maximum for $e\,(E-e)$ maximum that is $e = \frac{E}{2}$

$$\text{Greatest work of motor } B = \frac{E^2}{4R}$$

" " Pump $A = \frac{E^2}{2R}$

The practical efficiency of this combination of pump and motor will be diminished because the head E will require a coefficient greater than unity, and the counterhead e a coefficient less than unity.

$$\xi = \frac{e\,(1-x)}{E(1+X)}$$

The value of $\frac{1-x}{1+X}$ must be determined by experiment.

It will at once be seen that when the motor is acting at its greatest horse-power the theoretical efficiency is fifty per cent., and its practical efficiency still less, for we must introduce $\frac{(1-x)}{(1+X)}$ as a factor of $\frac{e}{E}$.

On the other hand, if we increase the counter head e, the efficiency of the motor B increases proportionally, but the weight of fluid per second $\frac{E-e}{R}$ becomes less and less, and the work of the motor B per second decreases as $\frac{e(E-e)}{R}$ decreases.

But the work of the pump A per second also decreases as $\frac{E(E-e)}{R}$ decreases, and the lost work due to resistance to flow through pipe and pumps decreases as $\frac{(E-e)^2}{R}$ decreases.

It seems hardly necessary to call your attention to a misconception on the part of some, and I should not do so now had it not very recently come to my knowledge that a professor, claiming recognition as a high authority in electrical science, is still making the statement that the greatest possible efficiency of an electric motor is fifty per cent.

With a theoretical efficiency of fifty per cent. an electrical motor is doing the largest amount of work in horse-power of which it is capable, but it demands of the generating dynamo twice as much power as it gives out. With a greater theoretical efficiency, it does not turn out so much work per second, but it makes a demand of less than twice its work upon the generating dynamo.

This statement requires to be modified somewhat because of the imperfections of machines, and becomes more accurate in proportion to the perfection of the machines used.

This work lost in resistance of the pipe is plainly a minimum for $E = e$, and a maximum for $e = o$ if R remains constant. Let us separate it into its component parts.

We see from the above equation that $\frac{(E-e)^2}{R} = \text{constant},$

when R varies as the square of the difference of the heads, or when the square root of R varies as the difference of heads.

If now we assume the resistance of the pumps as trifling in comparison with that of a long pipe or pipes connecting them, we see that we must double the difference of heads $(E - e)$ in order to have the same loss of work per second with a pipe four times as long.

Increasing the resistance four times gives us only one-quarter the weight of fluid per second assumed to be passing through the pipe, but doubling the difference of heads also doubles the weight of fluid per second, so that, under the altered conditions, we obtain one-half the weight of fluid per second, and twice the effective head. Therefore, the work per second lost in the pipe is

$$2\,(E-e) \times \tfrac{1}{2}\,\frac{(E-e)}{R} = \frac{(E-e)^2}{R}$$

as before.

The work done by the pump and motor, each working with twice its former head, remains the same as before, and their relative efficiency is the same.

This is what Marcel Deprez meant when he said:

"*The useful mechanical work and the efficiency remain the same whatever be the distance of transmission, provided the electro-motive forces, positive and negative, vary proportionately to the square root of the circuit's resistance.*"

I should like to emphatically call your attention to the deadly nature of the very high electro-motive forces demanded by this law, in the case of great distances.

One cannot but admire the boldness of this knight of science. In the face of mis-statement, based on erroneous assumptions, and of ridicule and opposition, in many cases becoming personal, he has adhered to his views and won his battle.

His detractors, while now forced to admit his results as correct, have shifted their argument from a scientific basis to a pecuniary one. One would think that so shrewd a financier as Baron Rothschild is not likely to be misled, and can safely afford to discount adverse editorial opinions, in the belief that a successful outcome will be reached before many years.

Let us hastily review the public experiments, which epitomize the results of his labors.

In 1881, at the Paris Electrical Exhibition, he exhibited in the Palace of Industry, one dynamo furnishing power to twenty-seven different pieces of apparatus. No measurements of efficiency were made, as the question of distribution was the only one then to be solved. He, however, then stated that it was possible to transport a useful work of ten horse-power thirty-one miles by means of an ordinary telegraph wire, with the expenditure of only sixteen horse-power on the generating dynamo, realizing sixty-two and one-half per cent. mechanical efficiency.

At the Munich Electrical Exhibition of 1882 over a line of telegraph wire thirty-six miles he obtained an electrical efficiency of thirty-nine per cent., and an actual mechanical efficiency of thirty per cent. In his experiments on the lines of the Chemin de fer du Nord, March 4, 1883, he transported 5·6 horse-power eight and one-half miles over ordinary telegraph wires, with 9·7 horse-power at the generating dynamo realizing an electrical efficiency of sixty-nine and one-half per cent., and a mechanical efficiency of fifty-eight and three-tenths per cent.

In his experiments, announced October 16, 1885, he obtained from his first, seventy-seven per cent. electrical, and forty-seven and seven-tenths per cent. mechanical efficiency. In the second experiment he obtained seventy-eight per cent. electrical and fifty-three and four-tenths mechanical efficiency by means of dynamometric measurements. The distance between these two points is fifty-six kilometres, about thirty-five miles. The speed of the generator varied from 170 to 190 times a minute, and there was no appreciable heating.

Tabulated results of experiments of Marcel Deprez—Convection of work between Creil and Paris:

	First Experiment.		Second Experiment.	
	Generator.	*Motor.*	*Generator.*	*Motor.*
Turns per minute,	190	248	170	277
Diff. of potential,	5,469 Volts,	4,242	5,717 volts,	4,441
Current,	7·21 ampères,	7·21	7·20 ampères,	7·20
Work in field,	9·20 H. P.,	3·75	10·30	3·80
Work in armature,	53·59 "	41·44	55·90	43·40
Measured mech. work,	62·10 "	35·80	61·	40·
Electrical eff,	77 per cent.		78 per cent.	
Mechanical eff,	47 7-10 per cent.		53 4-10 per cent.	

Resistance of line, 100 ohms.
" " generator, thirty-three ohms.
" " motor, thirty-six ohms.

Diameter of copper wire = five millimetres.

$$\frac{35{\cdot}80}{62{\cdot}10 + 9{\cdot}20 + 3{\cdot}75} = \frac{35{\cdot}80}{75{\cdot}05} = 0{\cdot}477, \text{ for first experiment.}$$

$$\frac{40}{61 + 10{\cdot}30 + 3{\cdot}80} = \frac{40}{75{\cdot}1} = 0{\cdot}534, \text{ for second experiment.}$$

The labors of Marcel Deprez have both theoretically and practically opened the way and proved the entire feasibility of transporting great amounts of power for long distances. Much remains and will yet be accomplished in the way of cheapening the first cost of apparatus required, and also of rendering it automatic.

Perhaps the first condition to be placed upon a motor used in manufactures is that its speed shall be regular under all variations of load. Now, we know that with a constant field intensity H and length L, of armature wire, the speed V, and the counter electro-motive force e, vary together.

$$e = HLV \qquad \frac{e}{HL} = V = \text{constant.}$$

We see, then, that if we demand a constant speed and cannot vary the length of the armature wire, the intensity of the field must vary with the counter electro-motive force.

This can be accomplished by means of double enrollment, commonly called "compound winding," patented by Marcel Deprez, in 1881.

I have already explained to you how the lines of force of the field are led by iron cores, surrounded by coils of wire, to the spot where the armature, in revolving, can cut them. If the whole current generated in the armature is led through the coil around the magnet, and then through the external circuit, the winding is technically called series winding. If only a part of the current is taken off at the binding posts of the machine, and led through the coils around the magnet and back to the armature, the winding is technically called shunt winding.

The resistance of the shunt-wound magnet coils is usually much greater than the external circuit, but the number of turns also is greater, and so we attain a field of equal intensity.

Compound winding consists of the joint use of these two methods.

Mr. F. J. Sprague has recently (April 7, 1885,) patented a very clever combination of shunt and series winding for the purpose of

obtaining a constant speed of motion for a constant potential circuit, such as is ordinarily used for incandescent lighting.

$$\frac{e}{H} = \text{constant} = \frac{e_1}{H_1}$$

Let R_s = resistance of shunt field coils.
" N_s = number of turns of shunt field coils.
" R_d = resistance of series field coils.
" N_d = number of turns of series field coils.
" E = potential at terminals of motor.
" I = intensity of current through series coils.
" R = resistance of armature.
$E - R_d I$ = potential at shunt terminals = E_s.

$$\left.\begin{aligned} \frac{E - R_d I}{R_s} &= \text{ampères in shunt coils.} \\ \frac{E - R_d I - e}{R} &= \text{" " armature.} \end{aligned}\right\} = \text{ampères in series coils.}$$

from the first equation we have

$$\frac{e}{N_s \frac{E_s}{R_s} - N_d \left[\frac{E_s - e}{R} + \frac{E_s}{R_s}\right]} = \frac{e_1}{N_s \frac{E_s}{R_s} - N_d \left[\frac{E_s - e_1}{R} - \frac{E_s}{R_s}\right]}$$

$$\text{Eliminating } \frac{N_s}{N_d} = \frac{R + R_s}{R}$$

The magnetizing currents in shunt and series windings are sent in opposite directions, and the number of shunt windings is to the number of series windings, as the sum of the resistances of the series windings and the armature is to the resistance of the armature.

This condition produces a magnetic field whose intensity is directly proportional to the counter electro-motive force, provided the magnets have not reached saturation.

Mr. Sprague, by ingenious devices, causes the currents to act together to start the motor with a very strong effort, and, once started, reverses one current and sets the contrary currents in the field coils to balancing each other, so as to produce a constant speed.

For constant potential circuits, this motor will not govern if its theoretical efficiency is less than fifty per cent. On the other hand, for constant current circuits such as are used for arc lighting,

this motor will not govern if the theoretical efficiency is greater than fifty per cent. We need not discuss it.

To avoid sparking at the brushes, Mr. Sprague has added a third series coil, which causes, in the case of dynamos having consequent poles, a counter distortion of the poles of the field magnet proportional to the increase of strength of the armature magnet.

Indeed, it would seem as if he had come very near realizing the ardent desire of all mechanics regarding their machines: "Once in order always in order." For economical reasons, motors running on arc circuits with a constant current, should have other methods of governing than the use of compound reversed coils.

Mr. Weston uses two methods for obtaining a constant speed. The first is by using belts upon reversed cone pulleys, which, with the aid of a centrifugal governor, shift so as to retain a constant speed for the driven machine, whatever be the variations of speed in the motor. The second is to vary the intensity of the field by means of resistance controlled by a governor or other automatic device. In our equation of condition for a constant speed, we observed two suggested methods of procuring this constant speed. The first was to vary the intensity of the field with the counter electro-motive force. The second was to vary the length of the wire in the armature coils.

This latter is manifestly impossible with the ordinary forms of machines, although it is not impossible that part of the field might be cut off, or the armature itself partially removed from a constant field.

Another way is to vary the counter electro-motive force of the motor by shifting the brushes around the commutator, but this is usually productive of sparking, and results in injury to both brushes and commutator.

The number of variations of this method is legion, and I would only weary you by recounting them.

For the purpose of locomotion, special arrangements to produce a uniform speed are not required. From all parts of the civilized world we learn the steady progress of the successful application of dynamic electricity to problems of locomotion.

In the transmission of power by electricity, the ends to be reached can well be stated under these heads:

(*A.*) Each receiving apparatus should receive its part of the

generated power, and, whatever be its action, should not influence other apparatus on the same circuit.

(*B.*) The efficiency must be independent of the number of apparatuses in action.

(*C.*) When a regular speed is desired, the regulation should be automatic and instantaneous, and should not require the intervention of an attendant.

Coming, as I do, from almost a year of unremitting experimental labor in a very small portion of the field I have this evening attempted to cover in an hour, I can only compare my lecture to an attempt to compress a bushel of solid matter into a quart measure.

I hope, however, that I have led you to believe with me that there is nothing of the mysterious left in the laws of dynamic electricity, and that with our thorough knowledge of its laws, a thousand heads, a thousand hands will make it transport to us at will heat, light, power, sound, sight, and chemical work.

MARKS: CORRECTION AND SUPPLEMENTARY FORMULA

THE LAW OF CONDENSATION OF STEAM.

JOURNAL OF THE FRANKLIN INSTITUTE, February, 1886, page 136, line 6 from the bottom, reads:

Dividing the condensation ·0125 by 3·80 and multiplying by 4·475, we have ·0146 for the corrected value.

Line 2, from the bottom, reads:

Dividing $C = \cdot 0088$ by 4·968 and multiplying by 8·22, we obtain ·0145.

For expansions greater than 2½ times, we can more accurately assume formula (7) JOURNAL OF THE FRANKLIN INSTITUTE, March, 1884, which is:

$$\text{Actual steam} = W_a = 62\tfrac{1}{2}\,\frac{e\,V}{S} + \left[(T_b - T_e)\,\frac{\pi\,d}{2\,N}\,(d + 2\,e\,s)\right] C$$

to become

$$W_a = 62\tfrac{1}{2}\,\frac{e\,V}{S} + \left[(T_b - T_e)\,\frac{\pi\,d}{2\,N}\,(d + 1{\cdot}6\,e\,s)\right] C$$

This latter formula will give sufficiently accurate results for cut-offs not exceeding 0·4 stroke, but the general and accurate formula (9), JOURNAL OF THE FRANKLIN INSTITUTE, February, 1886, must be used for all later cut-offs.

RAPID TRANSIT AND ELEVATED RAILROADS, WITH A DESCRIPTION OF THE MEIGS ELEVATED RAILWAY SYSTEM.*

By Francis E. Galloupe, M. E., Boston, Mass.

[*Continued from Volume CXXI, page 149.*]

V. THE TRUCK.

The truck which has been found best adapted to the peculiar form of way has been designed and constructed as a development of the considerations governing the adoption of the permanent way. *Fig. 45* shows an end view, *Fig. 46* a side elevation, and *Fig. 47* the plan view. It consists of a horizontal rectangular wrought-iron frame, *1*, *Fig. 47*, stiffened by cast-iron pieces, *2*, *Figs. 45* and *47*, and provided with stiff cast pedestals, *4*, *5*, *6*, bolted to its under side, in which are fixed short axles for the wheels. The supporting wheels, *7*, of each truck are four in number and have a notched rim or right-angled groove which fits the angle-iron rail upon the upper corners of the lower track-stringers, being placed at an angular position of about 44° 50′ with the vertical, so as to run upon it, the axles being inclined.

Between the supporting wheels are two horizontal wheels, *8*, one on each side of the girder, upon vertical axles attached to the truck frame, and bearing upon the vertical rails on the upper track-beam of the girder. These move to a limited extent in sliding boxes, *9*, *Fig. 47*, to which their axles are affixed, are kept in yielding contact with the rails by springs outside the boxes and serve the purpose of balancing wheels to take side oscillations of the cars. They have flanges which lip under the lower edge of the rail-plates and thus tie the truck to the rails so that no lifting or jumping can take place, or the possibility occur of the trucks running off the track.

The truck wheels, which are large, being forty-two inches in diameter, yet light and strong, have a broad tread of three and one-half inches upon each bearing face, and rotate independently of each other upon large fixed axles, surrounded by a loose sleeve, which divides the friction. They are lubricated by oil, carried within the axles, which are hollow, so that the journals constantly run in a bath of oil, none of which can drop out by reason of caps tightly screwed over the hubs of the wheels upon the under side.

*A paper read at the Boston meeting, 1884, of the Amer. Soc. Mechanical Engineers, and reprinted from advance sheets of the *Transactions*.

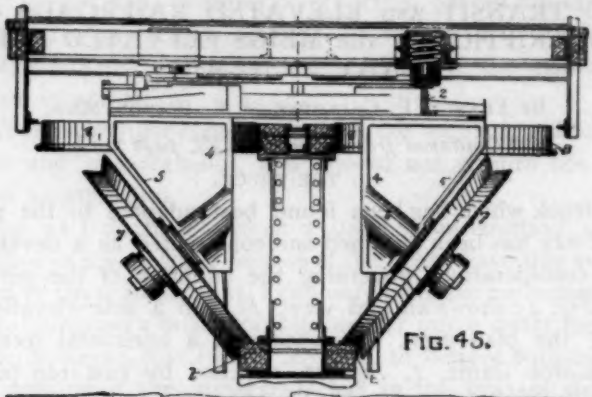


Fig. 45.

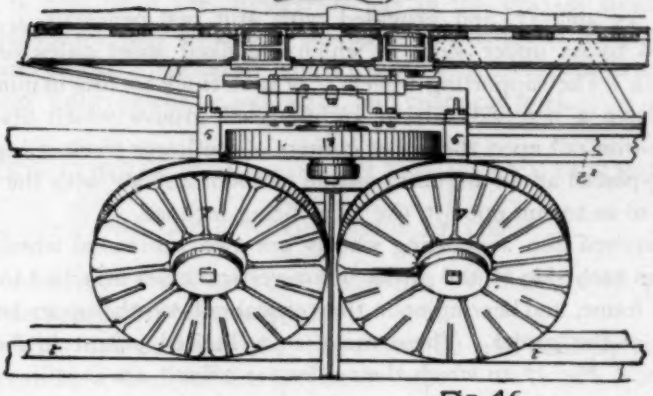


Fig. 46

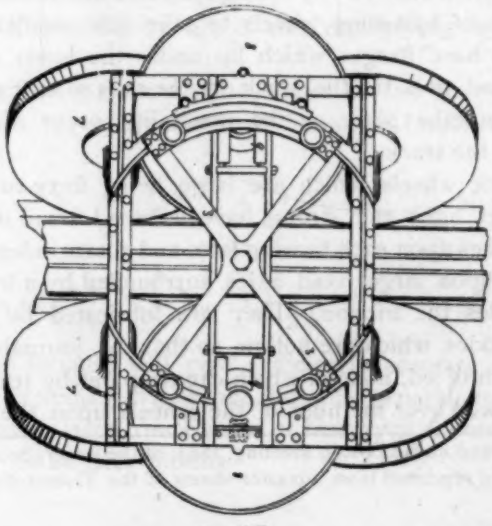


Fig. 47

Between the supporting wheels on either side of the girder are strong safety braces of T iron, extending from the pedestals, *5*, to points opposite yet so as to clear the rails by a small amount; and since the wrought-iron frame of the truck comes immediately above the girder, should any or all of the truck wheels break and even fall off, the frame would fall but about an inch before resting upon the girder, forming a strong shoe, which would slide upon, but could not leave the way, or allow the cars to overturn. That is, even in case of the breakage and absence of all the truck wheels, the framing alone could not leave the way, without lifting it through a space of over four feet, the entire depth of the girder, and this shoe is made sufficiently strong to maintain the cars, even then, in position upon the way.

Upon the top of the truck frame is a wrought-iron movable frame, *3*, *Fig. 47*, of segmental shape, carrying four spring posts containing heavy spiral springs, the posts interlocking beneath their upper flanges with similar spring boxes or sockets securely bolted into the floor framing of the car, which comes directly above the truck, within eighteen inches of the top of the girder. A centre-pin serves to guide the turning of the truck beneath this upper frame, and horizontal flanges of the truck frame castings overlap the periphery of the upper turn-table, thus as effectually tying the car body to the truck as the latter is tied to the rails.

The distance between the supporting wheels is four feet, which thus forms the rigid wheel-base of the truck, the trucks turning at curves and switch angles upon the balancing wheels placed centrally between them. Appliances for the transverse movement of the latter upon curves are also provided, which it will not be necessary to detail.

The theory of this truck is very simple, but yet has been found liable to constant misconceptions. To explain its principal features let it be conceived, in the diagram, *Fig. 51*, that *A* is a platform, assumed to be one foot in length perpendicular to the plane of the paper, loaded with an uniformly distributed weight of 4,000 pounds. Let *a a* be vertical posts supporting this platform, in the first instance, each of which posts would then sustain 2,000 pounds of load. Let *B* be a central post, and removing the posts *a a* substitute the diagonal braces or supports, *b b*. These diagonals now support the

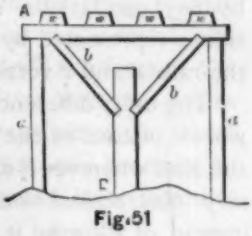


Fig. 51

same load as before, but the stresses in the braces *b b* will be greater than those in the former posts, *a a*, in proportion to the cosine of the angle that *b* makes with the vertical. For, the resultant resistance of the brace, *b*, acting opposite and equal to the stress due to the weight of the load, taking the direction and magnitude of the latter on any scale to be *A R*, *Fig. 52*, may be resolved into the two forces, *A a* and *A c* at right angles, *A c* producing an outward strain in the platform *A*, and *A a* being the component, in magnitude and direction due to the weight acting directly downward, or equal to 2,000 pounds. Hence it follows that the load in the direction *A R* is greater than that due to the weight, or *A a*; or

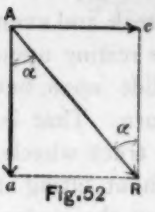


Fig.52

$$A\,R = \frac{A\,a}{\sin\,a} \text{ and } R = \frac{2{,}000}{.705047} = 2{,}837 \text{ pounds.}$$

Now, to support the weight upon a post and girder in this way, *B*, *Fig. 53*, being an end view of the way, a shouldered stick having a bearing against the upper rail at *a* may be used to carry the load, bearing upon a notched stick, *b*, at the other end, made to fit upon the lower rail at *c*, which would thus support the load. The resultant of the weight, *W*, acting downward upon one side of the posts will be to produce a downward pressure along the centre line of *b* upon the lower rail, *c*, and a horizontal pressure upon the upper at *a*. Now the supporting and balancing wheels of the truck are placed in precisely the positions these braces would occupy to support the load in the best manner upon this way. *Fig. 53* represents one-half, or one side of the truck. Of course the same thing would be true of the other side, and the leverage against the overturning of the car by any oscillations, unbalanced loads, or wind-pressure upon its side is represented by the depth of the girder, or distance between the rails *a* and *c* vertically, which is about four feet.

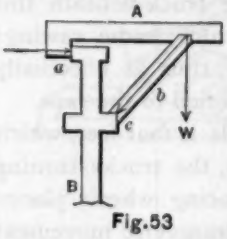


Fig.53

The only difference is that in place of the fixed brace, with the wheels instead of the props a rolling brace is obtained, supporting the load wherever it exists, and removing so much heretofore necessary obstruction from the street by transferring it to the truck instead of allowing it to remain in the permanent way.

From what has been said it will be seen that the angle of the truck wheels will not necessarily be 45°, but dependent upon the proportions given to the permanent way. They are actually laid out as follows: Let *B*, *Fig. 54*, be an end view of the way, *a* and *c* the rails. From *a* as a centre with a radius *a c*, strike an arc *k c l*. Upon the same scale cut off a portion of the arc from *c*, with the chord *c d* equal to the middle diameter of the wheel. This chord will form with the vertical the proper angle to use for the wheel; and bisecting this, *b*, the position of the axle is found, which is maintained, together with the remaining bracing needed, in the construction of the truck frame itself.

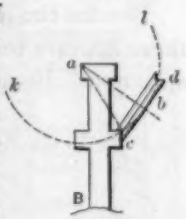


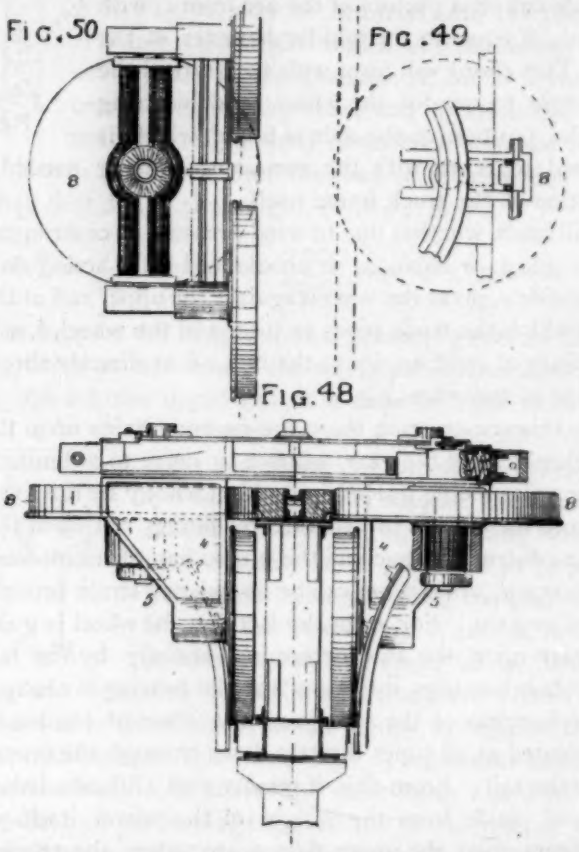
Fig.54

For all loads, whether due to wind-pressure or centrifugal action upon the side *a*, or balanced or unbalanced loads acting downward upon the side *c*, press the wheels against the upper rail at the point *a*, about which the truck tends to turn, and the wheel, *b*, will transmit the force at right angles to the line *a b*, or directly through the centre line of the wheel *b c*.

With this construction there are no end strains upon the hubs of the wheels, since they are left free to move to a limited extent along the axles, being guided in position wholly by the lower rails. This allows the wheels to separate by sliding out upon the axles, should an obstruction, such as the protruding of a bolt-head, exist upon the track, while there can be no twisting strain brought upon the wheel or axle. For, from the fact that the wheel is guided and its position upon the axle determined entirely by the rail, there being no hub bearings, it follows that the bearing is always square upon the bottoms of the axles, and the effect of the load is thus communicated at all times directly down through the centre of the wheel to the rail. From this it results that all loads, balanced or unbalanced, aside from the weight of the wheel itself which of course bears upon the upper flange, are, when the truck is once properly proportioned, equally distributed over the vertical and horizontal surfaces of the lower rails. For, since the force of the load acting vertically downward may be resolved into two forces at right angles, one acting through the centre line of the wheel and the other along the axle, the wheel with no end bearings to the hubs would move until the latter component force becomes

balanced and neutralized, or, in other words, it would slide upon the axle until the pressure of the wheel upon the vertical and horizontal surfaces of the rail is equalized.

Besides the increase of load due to the inclination of the wheels, there appears to be but one other mechanical objection to the construction. Because of the varying diameters of the wheels at different distances from the centre line there will be a slip of the rims in every revolution equal to the distance they will travel in a revolution beyond that of the central element. This will probably not prove more objectionable than the present flange friction existing upon railroads, and may be improved by slightly flaring the grooves upon the sides so as to bring the bearing principally near



the central portion of the wheel rim. It may be entirely avoided by the use of ordinary rails placed at the proper angle, and providing the wheels with a flat tread at right angles to the centre line, with double flanges upon the edges.

By reason of the independent motion of all the truck wheels, which is rendered practicable only because the design of the truck prevents the possibility of derailment from any cause short of the destruction of the way, curves are followed so closely that, practically, the increase of friction of the cars upon curves even as small as fifty feet radius, is too slight to be noticed or measured by weighing in a model one-eighth of full size. The construction also admits of a car fifty feet in length turning by means of these trucks from a street but twenty-eight feet wide into another of the same width.

In *Figs. 48–50* is shown an alternative plan of construction for the truck. It is provided with vertical instead of inclined supporting wheels having flanges upon their outer rims, and is designed especially with a view to the use of electricity as a motive-power. *Fig. 50* shows a dynamo-motor for

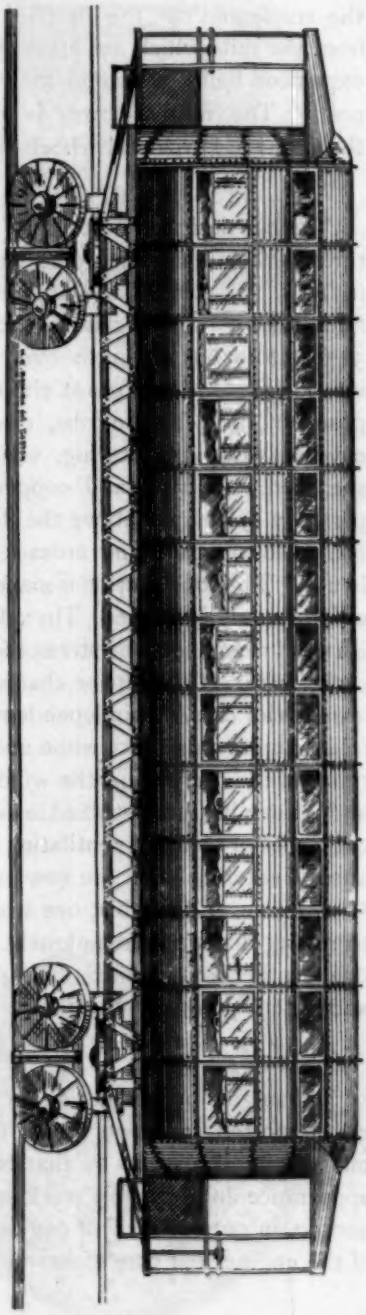


Fig. 55. Scale 1/8" = 1'.

the truck and car, the electric current in this case being derived from the rails, which are insulated from the girder for the purpose, expansion being provided for by cables at the slip joints of the posts. The motive-power is conveyed to the truck and cars through the horizontal wheels, which act as the driving wheels.

VI. THE PASSENGER CAR.

The car designed by Captain Meigs is novel in many of its features. An outside view, end view, and cross-section are illustrated in *Figs. 55, 56* and *57*. It consists of a strong well framed platform built of 5-inch channel beams, 7 feet 6 inches in width by 51 feet 2 inches in length over all, attached to the trucks by four interlocking spring posts at either end. The body framing is composed of light T iron ribs, circular in form, filled in by panels covered with upholstering, which covers the entire interior, and sheathed with paper and copper upon the exterior. The car is perfectly cylindrical above the floor, 10 feet 8½ inches in diameter, inclosing the same cross-sectional area as the standard car in use. The construction is made as light as possible, and strength of form carefully studied. The cylindrical shape is expected to diminish wind resistances and stresses fully one-third as compared with the ordinary car. The seats or chairs, fifty-two in number, are arranged as in parlor cars, *i. e.*, independent, revolving, and also automatically folding up to gain space when unoccupied. They, like the whole interior of the car, except the windows, are upholstered, and comfort and luxury has been studied in every detail. The chairs, as well as the device or securing ventilation at each window without the annoyance of entering dust, are new and special devices of the inventor. If it were ever desirable, one would become more easily reconciled to rolling down an embankment in one of these cars than in that of any other known form, for the entire absence of sharp corners and salient points is noticeable.

VII. THE ENGINE.

The engine or locomotive for this system comprises a platform car supported upon two trucks, one at either end, housed in similar manner in all respects to that of the passenger car. Its general appearance and principle working parts are shown in *Figs. 58, 59*, and *60*, in outside view of engine and tender coupled, a front view of the engine, and plan of engine floor with the locomotive mechan-

Fig. 56.

Scale 3/16" = 1'

Fig. 57.

ism and boiler upon it, the position of the latter being shown by broken lines. The engine floor is 7 feet 6 inches in width and 29 feet 3 inches in extreme length ; that of the tender, carrying tank and bin for the water and coal, being 25 feet 8 inches in length, allowing additional room for baggage or the transportation of employés, or for other purposes. Upon this floor in the engine, covered with one-quarter-inch iron plates, in effect two complete stationary engines are supported, each connected to and operating a single driving wheel, the pair being horizontal in position and opposite each other on either side of the upper track-beam of the girder and midway between the trucks.

A boiler of the locomotive type, though shorter, being 60 inches in diameter of shell, and 15 feet in length over all, is placed over the engine mechanism, its centre line being 61 inches above the floor. It contains about 200 tubes, 2 inches in outside diameter and 7 feet long, with a grate 4 feet 6 inches square, containing 20·25 square feet area. For city use anthracite coal will be used for fuel. The crown sheet is arched or elliptical in shape, stayed to the outer shell by radiating stay rods, and is inclined downward four inches at the back end, to allow of the climbing and descending of grades equal to 800 feet to the mile, without exposing any portion uncovered by water to the furnace fire.

The cylinders, 12 inches in diameter by 22 inch stroke, are horizontal, their centre lines placed 18 inches above the floor of the engine and 61½ inches apart. The piston rods connect with independent cross-heads sliding upon steel guide rods 2½ inches in diameter and 22 inches centres, these being supported at their ends by cast-iron standards bolted to the floor beams.

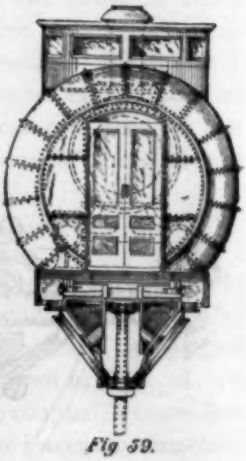


Fig 59.

The driving-wheels, 44·6 inches in diameter, flanged upon their lower edge, in form and position similar to the balance wheels of the trucks, are supported and rotate upon short stout axles of steel, six inches in diameter, which extend through a sliding-box containing the journals. These boxes slide in cast-iron ways transversely to the longitudinal line of the engine, the axle having a crank keyed upon its upper

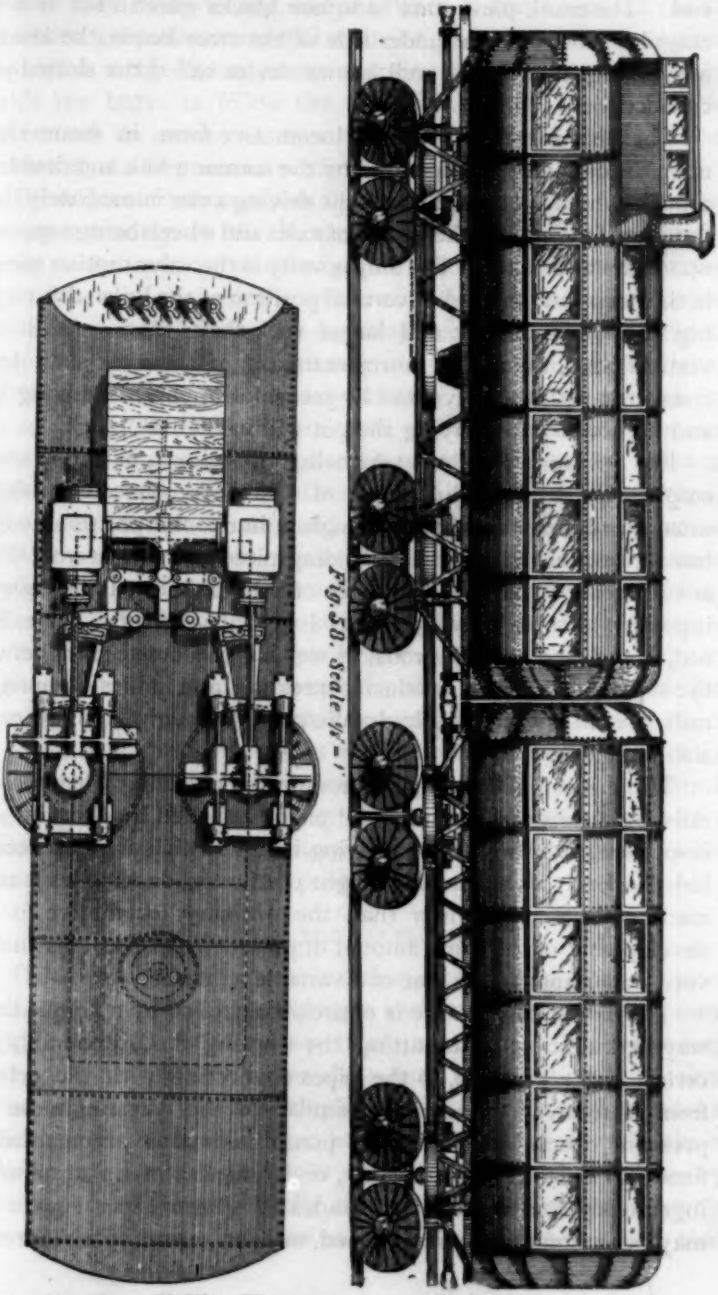


Fig. 58. Scale ⅜" = 1'.

Fig. 60. Scale ⅜" = 1'.

end. The crank-pins rotate in square blocks which slide in a rectangular groove in the under side of the cross-heads, the arrangement being in effect the well-known device called the slotted yoke connection.

The slide valves of the usual locomotive form, in steam chests upon the cylinders, are operated by the common link and double eccentrics which are here put upon the driving axles immediately above the floor of the engine, the weight of axles and wheels being supported upon a collar beneath. The only novelty in the valve motion consists in the horizontal instead of vertical position of the links, this requiring somewhat heavier and larger rock-shafts than usual, having vertical axes, the upper horizontal arm of the rock-shaft being connected with the valve rod by means of a short swinging link, and the lower arm carrying the pin within the link block.

For operating the links two bell-cranks shown in the plan are employed, the longitudinal arms of which are connected with the usual link-hanger and strap, though in horizontal position, and the transverse arms with a central sliding piece of wrought iron, which in turn connects with the plunger of a hydraulic cylinder, some 2 inches in diameter by 15 inches long. The throttle valve, link rod, brake and coupling rods, as well as the connection between the driving-boxes for producing pressure and adhesion upon the rails, are all operated by hydraulic power, though hand levers are also retained.

The method of obtaining adhesion of the driving-wheels to the rails, by means of a cylinder and piston attached by pins and eyes respectively to the sliding driving-boxes, which is thus secured independently of the actual weight of the engine, enables it to be made considerably lighter than the ordinary locomotive for the development of the same amount of power. It also attains another very important object, that of a variable adhesion.

The extent of pressure is entirely controlled by a simple three-way hydraulic cock admitting the working fluid, preferably glycerine, under pressure, to the pipes connecting with the cylinder from a receiver or reservoir similar to the Westinghouse air-pressure drum. A hydraulic pump maintains automatically a fixed pressure in this reservoir, or by means of an accumulator ingeniously constructed two grades of pressure per square inch may be automatically maintained, one for operating the pressure

between the driving-wheels, and the other, lesser in amount, for all the other purposes connected with the operation of the engine. The object of the sliding-boxes carrying the driving-wheels is to enable the latter to follow the arc produced by the rails upon curves, and its extent of transverse sliding from a straight line connecting the two trucks is about six inches.

The engine driver occupies the front portion of the engine, the fireman attending to the furnace at the rear end. The former stands or sits upon an elevated platform, and has an unobstructed view of the way through the windows of the monitor roof. Before him upon a shelf are the five hydraulic cocks controlling, respectively, (1) the throttle; (2) the reversing apparatus for the links; (3) the adhesion of the driving-wheels; (4) the brake; and (5) the coupling rods of the entire train, while just above are steam and hydraulic pressure gauges and indicators, speaking tubes to fireman and conductor, whistle and bell ropes, comprising those adjuncts which secure safety and convenience in practical operation.

With an engine having these provisions for a grip upon the rails, any grades from a horizontal to a vertical can be climbed, it being a mere question of supplying sufficient lifting power by the engine.

While no provision has yet been made for connecting the two engines with their driving-wheels together, it being left for practical running to determine the matter, several appliances are in readiness to be added if necessary. This can be accomplished by a mechanical connection in the mechanism, or by the valve motion controlling the steam distribution, or by the independent means of a hydraulic cylinder or auxiliary steam engine to throw either driving-wheel over the dead-points, when needful.

VIII. THE COUPLINGS.

These are automatic in their action, interlocking when coupled, the nose of one draw-bar entering a socket upon the other to form a rigid bar between the two truck centres. A rod extending through them parallel to the draw-bars, and making butt joints when two draw-bars are coupled, controls the coupling hooks, which are similar to the Miller hooks, by means of slotted links of variable throw, and these hooks are operated in such a manner by moving the rods hydraulically that the engineman can uncouple any car in the train, from the engine. The object of this is that

in case of an impending rear or head collision, which are almost the only serious possibilities of accident existing in this system, the engineman, by one movement of the hydraulic cock controlling the couplings, can divide the train into segments consisting of separate cars, each having a brake which sets automatically upon detachment from the train, and thus, by partially destroying the momentum of the whole, cause the collision to take place by a succession of comparatively small blows from the engine and slowing section of the train, instead of by a single blow having behind it the momentum of the entire train. This is accomplished by a hydraulic cylinder and piston upon the tender, the piston-rod of which cylinder pushes upon the coupling rods, compressing springs upon them during traction, and which when pressure is relieved as by movement of the controlling cock or breaking apart of the cars from any cause, causes the rods to spring out, withdrawing the hooks and uncoupling the cars.

Since the cars can neither lift nor swerve from the track by this construction of the coupling and of the trucks, end strains can only be brought upon the car platforms directly in line with them, strength to resist which is the leading feature of their construction.

The draw-bars and couplings have special devices for a continuous and positive connection throughout the train, although allowing the draw-bars to swing upon the truck centres, and contain new features of construction.

IX. THE BRAKES.

The purpose of a brake is to consume the power, momentum or energy of a moving body, such as a train of cars, by creating friction upon the wheels or rails, and it is in this system intended to be operated upon the horizontal or balancing wheels of the trucks, although they may be fitted upon the supporting wheels also. In the former case, they may be automatically operated by powerful springs acting upon toggle-joints so as to cause the wheels to pinch the upper track-beam of the girder, or by shoes upon their rims, controlled in either case by hydraulic means similar to those of the couplings. It is considered preferable to employ spring pressure to throw the action of the brakes on, and positive pressure by the hydraulic cylinder, to throw the friction off, during draft of the train.

It has been found in the Westinghouse brake experiments that the most efficient action of the brakes exists at the point of greatest pressure upon them before slipping of the wheel takes place. If the wheels slip, the friction is at once greatly reduced. That is, more power can be consumed by braking upon the rolling wheels than by the sliding of the same wheels without turning, upon the rails. It is well-known also that in the ordinary form of brake the pressure comes upon but one-half of the longitudinal cross-section of the axle or one-fourth of the brass, owing to the use of half boxes, and the position of the brake block with reference to them.

In this method it is resisted by the full half section of axles, which are made large for the purpose, and the momentum of the train is consumed not only by the friction at the brake-shoe, but upon the axles and rims of the wheels pressing upon the rails, *which latter is doubled, with the same braking force*, by the equal friction produced upon the opposite wheel on the other side of the girder.

The action of the brakes as well as that of traction can be best illustrated by the rails rolling between the rolls of a rolling mill. It is this well-known action reversed, and it is easily seen why no slipping of the wheels can occur by any pressure upon them. Indeed, as in the case of the transmission of pressure through the supporting wheels of the truck directly through the centre of the wheels, which has been discussed, the greater the pressure or load the more these actions are insured.

It should be said that the brakes just described are additional to the ordinary hand-brakes with which each car is to be supplied for use in an extraordinary emergency.

Continuing the discussion of the principal details of this system which have been described, there remains room for the short examination of a few leading points only.

The weights of engine and cars as actually under construction will be about as follows:

			Pounds.
Weight of	each truck, complete,		6,400
"	engine carriage, exclusive of boiler and engine,		20,336
"	engine mechanism,		11,075
"	boiler, empty, about,	6,500 lbs. In ordinary working condition,	8,500
"	engine, with boiler, complete,	38,000 " In ordinary working condition,	40,000

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" engine mechanism,				11,075
" boiler, empty, about,	6,500 lbs.	In ordinary working condition,		8,500
" engine, with boiler, complete,	38,000 "	In ordinary working condition,		40,000

				Pounds.
Weight of tender, complete,	.	22,925 lbs.	In ordinary working condition,	.*42,000
" car,	. . . .	25,000 "	Loaded,	. . 32,000

There being the same number of supporting wheels for the weight as in the ordinary system, or eight for each engine or car there will be:

	Pounds.
Load per supporting truck wheel on engine, with ordinary working load,	5,000
" " " " tender, " " " "	5,250
" " " " car, " " " "	4,000

Centre of Gravity.—The centre of gravity is considerably lower and the stability greater in this form of railway than in either the New York elevated or in the surface roads. It lies within a few inches of the floor of the car, when loaded, or about twenty inches from the way and rails, while in the other systems named it is nearly four feet above the rails. The principal feature in this construction of way is the low point of support for the load, in connection with a high-placed abutment for draft and brake power.

Curves and Centrifugal Forces.—Upon curves, the way is found to be even stronger in form than upon the tangents, since the action of centrifugal forces at these points has been found to act upon the line of tangent posts, while the hoop form of the girder, so long as it is preserved intact, effectually prevents any concentration of stress upon any single post tending to overturn it. To avoid all locating of posts in the streets, which is always desirable, in turning from one street into another, diagonal trusses may be thrown across from the opposite corner of the street, and the track girders supported upon them, giving all required intermediate support.

Tractive Force and Resistances.—The actual tractive power which it will be necessary to employ in the Meigs system can be determined only by experiment. The resistance to movement of an ordinary freight car on a straight and level road at ten miles per hour is about eight pounds per ton weight, and the total may be divided into a constant resistance due partly to the internal resistances of the friction of the axles, and partly to the external resistances of the rolling friction of the wheels upon the rails; and vari-

* With 1,800 gallons water, weighing 15,000 pounds, and 4,000 pounds of coal.

able resistances. The latter include additional resistances caused by flange friction upon curves and by gravity on ascending grades, the friction of the engine and its machinery, the resistance of the atmosphere and of wind, and those caused by the lateral play of the wheels and transverse oscillations of the engine and train; and all these are affected by the condition of the engine and of the permanent way, the evenness of the track, curves and grades, the weather and wind. They are principally caused, however, by the speed, and increase as the square of the speed. The fact, ascertained by D. K. Clark, that the resistance of a train at sixty miles per hour was twenty-one pounds per ton, forms the basis of a formula deduced by Mr. Forney. Taking the constant resistance at six pounds per ton, since the resistance at any speed to that at a known speed, $R : R^1 = v^2 : v_1^2$, we have the resistance

$$R = \frac{R^1}{v_1^2} \cdot v^2 = \frac{21}{v_1^2} v^2 = 6 + \frac{v^2}{171}.$$

The resistances of the atmosphere also vary as the square of the speed, and according to the estimate of Mr. Zerah Colburn, in *Locomotive Engineering*, increase the above one-half, or fifty per cent. The ordinary resistance of curves is stated to be fully covered by a grade allowance of two and one-half feet per mile per degree.*

The total train resistances then, were this railway upon the ordinary system, may be taken at from sixteen to twenty pounds per ton weight of train, at moderate speeds. This would be, for engine, tender, and four cars, weighing in all 210 tons, from 3,360 to 4,200 pounds, exclusive of atmospheric resistances which would increase it to about 6,300 pounds.

The tractive power, or force exerted to move the engine with its train one foot is

$$T = \frac{2\,p\,A\,.\,2\,S}{2\,\pi\,R},$$

(p, being the mean effective pressure of steam per square inch of piston; A, the piston area, and S and R the stroke of crank and radius of driving-wheel, respectively); or, the tractive force which must be exerted in order to equal and overcome the above resistance for a constant speed of train may be found conveniently by

* H. Haupt, C. E.

multiplying the tractive power *per pound of effective pressure per square inch on the pistons* by the pressure per square inch of the steam upon the pistons. The first is obtained by means of the following formula reduced from that above, or

$$t = \frac{d^2 \times S}{D} = \frac{(12)^2 \times 22 \text{ in.}}{44{\cdot}6} = 71 \text{ lbs.}$$

(d and D being the diameters in inches of piston and driving-wheel respectively). The mean effective pressure exerted through the stroke, assuming the boiler pressure at 150 pounds per square inch, diminished to 130 pounds initial pressure in the cylinders, with the cut-off at one-third the stroke as usual, may be estimated at not far from 100 pounds per square inch of piston area; which, multiplied by the tractive power per pound, seventy-one, gives 7,100 pounds as the maximum constant force exerted by the engine at the rail, to pull the train.

Now the friction of the driving-wheels upon the rail, or the adhesion produced, which alone makes the exertion of the tractive force useful in moving the train, is in the ordinary system entirely dependent upon the weight or load upon the driving-wheels, and is but about one-fifth of this load in amount, on an average. Thus it appears that fully to utilize the power exerted in the cylinders of the engine, there would be required in the ordinary system a load upon the driving-wheels, or a weight of engine upon them of 35,500 pounds, in order to produce the adhesion of the wheels necessary to prevent their slipping. It is estimated that the actual loss by slippage of the wheels and absence of means to prevent the bouncing or jumping of the wheels from the rails upon railroads is not less than one-fifth their circumference in every revolution, causing a constant loss of power to an extent of twenty per cent. of the entire power of the engine. The area of actual contact of these wheels upon the rails has been found by measurement to be surprisingly small, an average of many experiments giving an extent of but 1¼ inches traversely to the rail by ¼ inch longitudinally—an area varying from $\frac{13}{100}$ to $\frac{42}{100}$ of a square inch, and averaging but $\frac{31}{100}$ square inch; from which it follows that the concentration of pressure upon these limited surfaces varies from 26,607 pounds to 85,961 pounds to the square inch, these enormous forces causing great wear and tear on the rails. It has been

stated by R. Price Williams, an authority upon the maintenance of way in England, that anything which will reduce the resistance due to deflection of track under these forces and consequent abrasion, by one-fifth or one-sixth, will soon effect the saving of the whole cost of the rail.

In the Meigs' system the bearings of the wheels upon the rails are increased about five and one-half times beyond those in existing railroads, while all bouncing from the track is effectually prevented, or at least its evil effects offset, so far as adhesion is concerned, by a corresponding pressure upon the opposite wheel, at the moment of occurrence. There can be no slipping of the wheels, when sufficient power is supplied, in a variable adhesion system; they will always roll, under light or heavy loads equally.

Now an ordinary locomotive having 35,500 pounds load upon the driving-wheels, to make available the 7,100 pounds tractive force we have assumed to be required in this engine, would have to weigh in all at least 60,000 pounds, or thirty tons, whereas this engine exerting the same power will need to weigh but twenty tons, a clear saving in dead weight to be transported, of ten tons, or thirty-three per cent. of the weight of the ordinary locomotive.

The importance of this saving, resulting from the use of means for producing a variable adhesion independent of the weight of engine and possible only upon the system of way adopted, or a similar one, demands particular notice.

Speed.—By this saving in power, an increase can be made in the size of the driving-wheels, to draw a train of equal size as now run, without a material increase in the expenditure of steam and coal; from which it results that with the same number of revolutions of the driving-wheels as that now secured, a large increase in speed is attainable, with the same power of engine. Thus, for example, a ten-foot driving wheel, without slip, would require but 168 revolutions per minute to make sixty miles per hour, while the ordinary five-foot driving-wheel requires to be driven at 336 revolutions per minute, even without slip, to run at sixty miles per hour, which it will be seen is nearly the practicable limit, producing a piston speed of from 1,200 to 1,400 feet per minute. Any large increase of speed beyond this amount can hardly be looked for upon the ordinary railroad, for the requirements of safety against derailment, and the safe working speed of the mechanism, together

with the exertion of sufficient power to move the load, are the limiting conditions which forbid the increase in size of driving-wheels against the rapidly and enormously increasing train and air resistances.

So that, it requiring but 280 revolutions a minute at usual speed of a ten-foot driving-wheel, to make 100 miles an hour, as compared with 336 revolutions with the ordinary five foot driving-wheel to make sixty miles an hour, it will be seen that an ample margin of steam is obtained, together with the absence of slip, to run at such speeds with equal or ordinary power. Thus it becomes perfectly possible and within the capacity of the present locomotive boiler and without increase of piston speed, to run trains at great speed upon the plan proposed, and the inventor confidently predicts regular working speeds of from seventy-five to 100 miles per hour upon this railway with equal and probably greater safety than that with which forty miles an hour are now run. The entire absence of connecting and parallel rods in this engine should be noted as an important point in the attainment of speed with safety from breakage in the engine mechanism.

Power.—Of course the power developed by the engine will vary with the number of revolutions made. Although the term, horse-power, is applicable to stationary rather than to locomotive engines, since as a general distinction the office of the latter is to draw a load rather than to lift a weight through a certain height, its power can be reduced to an equivalent horse-power, this being equal to the product of a certain weight attached by a rope to the circumference of one of the driving-wheels into a certain height through which it is lifted per minute, divided by 33,000. Since the power exerted is equal to the gross work performed, it may be represented, calculated from the effective steam pressure and the speed, as follows:

$$HP = \frac{p \times 2 \times A \times 2 \times S \times N}{33{,}000} = \frac{4\,p\,A\,S\,N}{33{,}000},$$

depending therefore upon the effective pressure, p, per square inch exerted through the whole stroke; the joint area, $2\,A$, of the two pistons; the length of stroke, S, in feet: and the number of revolutions, N, per minute. At sixty miles per hour with ten-foot driving-wheels, the foot-pounds of energy developed at 168 revolutions would be 13,921,606 per minute, and the nominal horse-

power, 422. At 100 miles per hour and 280 revolutions per minute the number developed would be 23,202,676 foot-pounds per minute, and the corresponding number of horse-power would be 703.

As to the train resistances at these speeds it can only be said that no data now obtained are applicable. Their actual extent is simply a subject for conjecture, and can be determined only by actual experiment.

It is evident that the same proportionate advantages may be realized with the adoption of electricity instead of steam as the motive-power, for which the system is especially well adapted, and which it is ultimately the intention to employ, with a consequent avoidance of dust and noise.

In conclusion, and in review there may be noted the following brief statement of advantageous points for the accomplishment of rapid transit, as indicated by this system.

Summary of the Chief Distinguishing Points of the Meigs Elevated Railway System for Rapid Transit.

(1.) Security from derailment by the construction of truck overhanging the girder and tied by the wheel-flanges to the rails.

(2.) The connection of the draw-bars and couplings to the trucks directly beneath the car platforms, preventing telescoping or rising of the cars in case of collision.

(3.) The increased security of the attachment of the car body to the truck, having four posts for each truck, in place of the usual single pivot-pin, and the tying of both together by interlocking flanges.

(4.) Obstruction in the streets and interference to light and view reduced to a minimum, due to the reduction in the width of the permanent way.

(5.) The advantage in strength of way due to bringing the stresses of the load directly over the central line of posts, by means of the diagonal supporting wheels.

(6.) The lowering of the centre of gravity and consequent increase in stability both of the cars and way, as compared with the New York system.

(7.) The advantage of independently rotating wheels for the prevention of slipping and flange friction, enabling each wheel to follow the rail more closely than in the ordinary truck, and thus greatly diminishing its resistance upon curves.

(8.) The increase in breadth of tread of the wheels upon the rails to prevent the concentration of the load upon small areas, and to thus reduce the wear upon the rails.

(9.) The saving of power attained in the production of pressure upon the driving-wheels by means independent of the weight of engine, and controlling the same so as to produce the variable adhesion required.

(10.) The lessening in cost of operation by the reduction in weight of engine and cars.

(11.) The cylindrical form of car and engine, for the diminution of air and wind resistances upon their sides and resulting strain upon the trucks and way.

(12.) The facility of turning sharp curves as small as those of fifty feet radius, enabling it to be constructed in narrow streets, not possible in the ordinary system, and the absence of increased friction and resistance upon the curves.

(13.) The facility and economy in climbing heavy grades without loss of power by slippage, and, in general, by the holding of the wheels against the rail without the possibility of rebounding from them, as in the ordinary system.

(14.) The superior advantage of the system proposed of brakes upon the upper or gripping rails.

(15.) The automatic coupling apparatus for diminishing the danger in head or rear collisions.

(16.) The increased safety of the switch due to its size and construction

(17.) The freedom of the way from obstructions, or from snow and ice lodging upon the way and blocking it.

(18.) The entire absence of grade crossings, of trespasses, or the possibility of other trains crossing at grade.

(19) The economy of construction and maintenance of way due to absence of surface grading, of embankments and drainage ditches, and diminished repairs in alignment, and the cost of the renewal of cross-ties.

(20.) The increased speed made practicable, with safety and economy, due to its special features as a system, as compared with the ordinary system now in use.

(*To be Continued.*)

PHOTOGRAPHY BY A LIGHTNING FLASH.

By Professor Edwin J. Houston.

[*Abstract of Remarks made at the Stated Meeting held November 18, 1885.*]

Mr. Albert S. Barker, of Philadelphia, has recently succeeded in taking two very fair photographic negatives of outside objects while illumined by no other light than that of a single lightning flash. These photographic views were taken at 7 P. M. on Thursday, October 29, 1885, near Philadelphia. The night was excessively dark, the wind strong, and the rain heavy. The camera was placed in an open window, with the slide drawn. The lightning flash came in less than one minute, when the slide was returned. The plate holder was then reversed and suitably placed for a second exposure. The plate was one of the highly sensitive gelatine films.

Mr. Barker developed the plates the same evening. From their behavior he rated the actinic effect of the light as equal to that obtained from an exposure of about $\frac{1}{300}$ part of a second in bright sunlight.

The popular impression as to the duration of the lightning flash is that it is practically instantaneous. From the experiments of Wheatstone and others with the rotating disc, the duration of the flashes measured, would vary apparently from the $\frac{1}{1000}$ to the $\frac{1}{10000}$ of a second. Others estimate the duration of the flash as even shorter than these figures.

It is very doubtful if the average severe flash in this latitude does not endure or continue for a very much longer period. Despite the popular belief to the contrary, the author has frequently observed the motion of foliage when illumined by no other light than the lightning flash. This would not, of course, be the case if the flash were even approximately instantaneous.

It is a very significant fact that in the photographs of Mr. Barker the foliage shows unmistakable evidence of having perceptibly moved during the period of exposure; thus showing that it was by no means instantaneous.

It is to be hoped that Mr. Barker, or some other photographer, will repeat these exposures under the following conditions, viz., to make the exposure while the camera is sharply focussed on

moving foliage, or a rapidly rotating wheel, while illumined by a lightning flash, so as to determine more definitely the duration of the flash.

In the case of the lightning flash, the large percentage of blue rays would of course render the plate more sensitive to the extremely short exposure by practically prolonging the same, since the ordinary photographic chemicals now employed are especially sensitive to the blue portions of the spectrum.

It would appear from the facts developed by the photographs, of Mr. Barker that the method of measuring the duration of the lightning flash as adopted by Wheatstone and others, which consist essentially in endeavoring to detect by the unassisted eye the change in position of a rapidly moving wheel, or other object, while illumined by the flash, might be greatly improved by substituting for the eye, the sensitive photographic plate since the latter is apparently far more sensitive than the eye.

Should photographic pictures of a rapidly rotating wheel, whose rate of motion was known, be taken while illumined by a lightning flash, the displacement of the image on the negative would give far more reliable data for calculating the duration of the flash than the methods heretofore employed.

Mr. Barker's photographs, therefore, are not only interesting as showing how extremely sensitive the photographic plate may be made, but are also of interest as throwing some light on the possible duration of the lightning flash.

CENTRAL HIGH SCHOOL,
Philadelphia, November 18, 1885.

ORIGIN OF DIASTASE.—Emile Laurent has investigated the question whether diastase is a product of bacterial action, or whether it can be formed without organic intervention. He placed seeds of lupin, maize, barley and helianthus to germinate under a bell-glass, over water which had been previously boiled, the seeds having been first freed from superficial microorganisms by the ordinary processes of sterilization. When the sprout began to show, the seeds were introduced, with all necessary precautions, into tubes containing Koch's nutritive gelatine. The seeds continued to develop normally, without liquefying the gelatine, which constitutes, according to Koch, an infallible criterion of the absence of bacteria. Sprouted seeds, introduced into sterilized plum juice, continued to grow, without showing any bacteria in the liquid. Although these experiments can hardly be considered as decisive, they lend great probability to Laurent's opinion that bacterial intervention is not necessary—*Bul. de l'Acad. Roy. de Belg., No. 7, 1885.*

CONTACT-MAKER FOR ELECTRIC CLOCKS.

By Louis H. Spellier.

It is well known that the seemingly easiest of all operations in time telegraphy has proved to be its weakest point, and its most obstinate obstacle to attain the perfection desirable for a universal adoption.

It is the contact maker for the electric circuit which has, in many instances, caused the condemnation of secondary electric clocks, the skilful execution and superior construction of which should have entitled them to more deserving consideration.

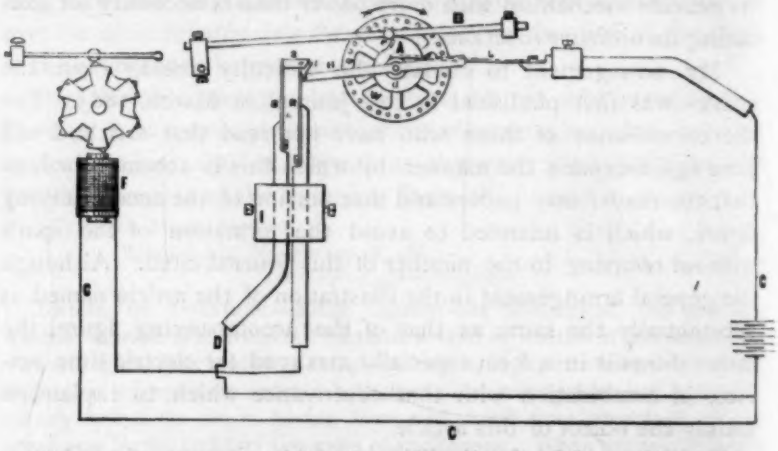
The obstacles that make the transmission of the electrical energy to the secondary electric dials difficult and uncertain, are mainly the effect of the spark resulting from the induced current at the contact terminals of the contact-maker, and the mode of operating the contact-maker by the main clock, without overtaxing its delicate mechanism with more power than is necessary for executing its ordinary functions.

My arrangement to obviate the difficulty arising from the sparks was first published in this journal in March, 1883. For the convenience of those who have not read that article, I will here again explain the manner by which this is accomplished, so that the reader may understand that portion of the accompanying figure, which is intended to avoid the formation of the spark without referring to the number of this journal cited. Although the general arrangement in the illustration of the article named is substantially the same as that of the accompanying figure, the latter shows it in a form especially arranged for electric time service, in combination with that contrivance which, to explain, is mainly the object of this article.

Referring to the figure, *E* is the electro-magnet of an electric clock; *H* is a metallic arm designed to produce the closings and breakings of the current. One of the poles of the battery is connected by the wire *C* with the spring *L*, which rubs constantly upon the metallic disc *d*. The latter is fastened on the shaft of the escapement wheel *W*. The other pole of the battery comes from the electro-magnet *E*, and is connected with a second spring

R, the projection *1*, of which, comes in contact with a metallic pin at the terminal of the arm *H*. When this contact is made, the current is closed, and *E* can attract its armature. What is now necessary is to avoid the spark produced by the extra current, as soon as the contact between the pin and *R* is broken, since it will occasion a defective contact of the current-breaker. For this purpose, another spring *S*, the terminal of which is also provided with an inclined projection *2*, is placed a little above *R*, and is connected by the wire *D* with the returning conductor. Both springs *R* and *S* are insulated from each other, and the clock movement by its bearing *I*.

After the pin has been in contact for a short time with the projection of the spring *R* only, it comes in contact with the projection of the spring *S* also. At this moment, the current passes through the short circuit *S D*. Since both springs are now for a moment in contact with the pin of the arm *H*, the extra current excited in the electro-magnet at the instant the short circuit is made by *S D*, takes its way through *C*, *D*, *S*, *R*, *E*



As stated, my main object is to describe in this article an improved method to operate the contact-maker by an ordinary regulator, which now may occupy our attention. Heretofore, the escapement wheel of any clock, when used for the making and breaking of an electric circuit, to actuate secondary electric clocks, did not exercise any more power at the moment the making and breaking of the circuit occurred, than it did while serving its real purpose, namely, to give to the oscillating pendulum of the clock

the impulses needed for the continuation of its movements. The power necessary for this purpose is very slight, and not energetic enough to make a reliable contact for the passage of the electric current. But since such a contact must be a firm one to make it secure, a frequent failure of forming a complete electric circuit may be a not uncommon occurrence. That this is a circumstance which will greatly interfere with the reliability of secondary electric clocks, needs no further demonstration.

Two methods, to avoid this evil, have been resorted to. One is the use of a relay. In that instance, the escapement wheel of the standard clock makes a very faint contact, sufficient for the passage of a weak electric current, to operate a relay. The relay then closes the main battery of a sufficiently strong current to actuate the electric dials in the circuit.

The other method, which was first executed by Paul Garnier, and which seems to have found at present, the greatest consideration, in Europe, is based upon the use of an extra clock-work, which is set in action and arrested again at fixed intervals by the escapement wheel of the standard clock. This extra clock-work operates the contact-maker of the electric circuit for the secondary dials, and is provided with ample power to effect a secure and firm contact.

If properly constructed and executed, this method has proved to be a very reliable one. Its main objection rests in the fact, that it is rather complicated in construction, and too costly to be purchased where but a few electric dials are desired, and, above all, an attendant of but little skill cannot be entrusted with the maintainance or repair of such an arrangement. This is a fact which may justly receive full consideration in many places, where an experienced mechanician is not at hand. To meet this emergency is the object of the device shown in the diagram. It is intended to enable us to use in a simple and yet effective manner the escapement wheel, or its shaft, of the standard clock directly for the making of a firm electrical contact. But since, as stated, under ordinary circumstances the escapement wheel has not sufficient force to accomplish this work, I have endeavored to invent a mechanism by which the escapement wheel, during the time the electric contact is made, receives an additional amount of power for the operation of the contact-maker.

Its action will be readily understood.

The escapement wheel *W* moves in the direction of the arrow. Besides the contact arm *H* its shaft carries, also rigidly fastened to it, the cam *A*. The pin of the arm *H* is now in contact with the projection of the spring *S*, for the purpose of completing the electric circuit. At this time an increase of the power exercised by the escapement wheel is needed, to overcome the obstruction offered by the tension of the contact springs. To arrive at this result is the purpose of the cam *A*, and the weighted lever *B*, which is pressing against the curve of the cam by a little roller *r*. It will be observed, that just now the roller of the lever presses against the incline *i* of the cam. Thereby it imparts additional power to the shaft of the escapement wheel by its pressure, and assists to overcome the obstruction offered by the contact springs. The moment the contact pin has passed the projections of both contact springs, the roller *r* of the weighted lever reaches the lower part of the cam. It is gradually raised again as the escapement wheel revolves, and will repeat the same operation at the next contact between the pin of the contact arm and the projections of the springs. It is hardly necessary to mention, that the whole mode of operation is but a gradual storing up of a portion of the power expended by the escapement wheel during the course of its revolution, which is returned to the same at the proper moment for the purpose demonstrated.

It is obvious that the relative conditions between the weight of the lever *L* and the tension of the contact springs can be easily so adjusted that when the shaft of the escapement wheel is impelled with increased force this increase is exactly absorbed by the tension of the contact springs, leaving for the functions of the escapement wheel only so much force as properly belongs to it.

All regulators that were provided with this contact-maker needed but a slight additional weight (in some instances even this was not needed). In no case were the time-keeping qualities affected to any perceptible degree.

In conclusion, I may mention, that the diagram also shows the three principal features of my system of time telegraphy systematically connected.

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS OF THE FRANKLIN INSTITUTE ON GREENE'S PROCESS OF EXTRACTING OIL AND ALBUMINOID MATTER FROM CORN, ETC.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 10, 1885.

The Committee of the Chemical Section as a sub-Committee of the Committee on Science and the Arts, constituted by the FRANKLIN INSTITUTE of the State of Pennsylvania, to which was referred for examination :

"THE PROCESS OF EXTRACTING OIL AND ALBUMINOID MATTER FROM CORN." BY DR. F. V. GREENE, OF PHILADELPHIA,

report that the invention has for its aim the separation of fatty and nitrogenous matter as a by-product from the liquors of starch factories, from which the starch has been deposited.

In the manufacture of starch, corn is steeped in water, and kept at a temperature favorable to promote fermentation and putrefaction, for the purpose of loosening the cellular tissue, and to liberate the starch granules as well as possible. In order to accelerate this process, an addition of a small quantity of alkali, preferably caustic soda, is generally made, while other manufacturers, for the dissolution of the inter-cellular matter, prefer the use of dilute acids, especially sulphurous acid

After twenty-four (24) to forty (40) hours standing, the steeped corn is reduced to a pulp by grinding, from which the starch is then obtained by brushing through sieves and an elaborate process of floating and settling. In the spent liquors, remain dissolved, the soluble parts of corn, such as sugar, gum, albuminoid substances, gluten, salts, etc., which hold in emulsion fatty and resinous matter, and also suspended cellular and other insoluble matter.

It is this milky liquid to which the inventor applies his process. The liquors are mixed with a small quantity of a solution of sulphate of alumina, which renders insoluble the albuminous substances (for the larger part). These in coagulating, envelop and precipitate the fatty matter, as well as the coarser particles, so that the liquor, after settling, is left almost clear. The precipitate is separated by subsidence or filtration, and pressing, and after proper drying, forms a grayish coarse powder, the by-product of starch

factories, as intended by the inventor. The same treatment is also proposed for the residues of distilleries and vinegar factories.

From the dry product, the oil may be obtained by pressure, or by extraction with benzene or bi-sulphide of carbon, and the exhausted residue is proposed as fertilizer for the sake of its nitrogenous matter. Mr. Trimble found 4·26 per cent. nitrogen in a sample; whilst Mr. Haines found 4·75 per cent. in another sample of this exhausted residue, which amount the inventor expects to increase to eight per cent. by improved operations. The quantity of oil obtained is reported by the inventor as being about one-tenth of the dry precipitate.

As far as your committee could judge, the oil, which in its crude state is dark-colored, has a good body, and is capable of bleaching. After all odor of the remaining extracting medium (hydro-carbons or bi-sulphide of carbon) is dissipated, the oil has a very agreeable flavor of its own. Undoubtedly, it would make a very satisfactory soap-stock.

Your committee had no chance to see the process carried out on a manufacturing scale, and no facilities to operate with larger samples, yet they are under the impression that it should work to satisfaction under otherwise favorable circumstances.

The drying of the precipitate, which, in its nature, must be very bulky and pasty, will undoubtedly be somewhat difficult and expensive; considering, however, that the waste waters will by this treatment at the same time be disinfected, the process would be a great boon to the whole community in removing a public nuisance—putrefying waste waters of starch factories. Its introduction should, therefore, be encouraged, even if it should fail to pay large profits as an enterprise of its own.

(Signed) OTTO LUTHY.
J. W. EASTWICK.
January 6, 1885. H. W. JAYNE.

Amended to incorporate the recommendation of the award of the "John Scott Legacy Medal and Premium."

Adopted as amended January 6, 1886.

(Signed) H. R. HEYL, *Chairman.*

I hereby certify that the above is a correct copy from the record.

[SEAL] (Signed) WM. H. WAHL, *Secretary.*

Franklin Institute.

[*Proceedings of the Annual Meeting, held Wednesday, February 17, 1886.*]

HALL OF THE INSTITUTE, February 17, 1886.

COL. CHAS. H. BANES, President, in the Chair.

There were present 120 members and twelve visitors.

Five new members were reported as having been elected at the last meeting of the Board of Managers.

The President delivered an inaugural address in which, after paying a warm tribute to the ability and devotion with which his predecessor—MR. TATHAM—had discharged the duties of President, he spoke at length of the "Influence of the FRANKLIN INSTITUTE on the Development of the Mechanic Arts in Philadelphia." Setting forth the capabilities for usefulness which the INSTITUTE should possess, when properly equipped for the work; giving a sketch of its past services; and presenting, forcibly, a plan to our citizens for aid in placing the INSTITUTE in new and enlarged quarters, and with adequate means and facilities for carrying on its work.

The address was ordered to be printed and 5,000 copies thereof in pamphlet form, issued for distribution to members and to the public.

The Secretary's report embraced a résumé of technical progress during the year 1885.

MR. RUDOLPH HERING followed with some remarks on "Steam Traps," illustrated with views, exhibiting faulty and correct constructions.

MR. WM. A. CHEYNEY made some remarks, giving his views respecting the future development of the INSTITUTE.

The President named the following as the Standing Committees of the INSTITUTE, for the current year, viz.:

Library.	*Minerals.*	*Models.*
Charles Bullock,	Clarence S. Bement,	Edward Brown,
J. Howard Gibson,	Persifor Frazer,	H. L. Butler,
Frederick Graff,	F. A. Genth,	C. Chabot,
Wm. D. Marks,	Edwin J. Houston,	L. L. Cheney,
S. H. Needles,	George A. Keonig,	N. H. Edgerton,
Isaac Norris, Jr.	Otto Luthy,	John Goehring,
A. E. Outerbridge, Jr.	E. F. Moody,	Morris L. Orum,
Chas. E. Ronaldson,	H. Pemberton, Jr.,	Chas. J. Shain,
Wm. P. Tatham,	Theo. D. Rand,	John J. Weaver,
Lewis S. Ware.	Wm. H. Wahl.	S. Lloyd Wiegand.
Arts and Manufactures.	*Meteorology.*	*Meetings.*
J. Sellers Bancroft,	John Bullock,	Hugo Bilgram,
George Burnham,	Wm. A. Cheyney,	A. B. Burk,
George V. Cresson,	Charles M. Cresson,	G. M. Eldridge,
Cyrus Chambers, Jr.,	J. A. Kirkpatrick,	Frederick Graff,
Wm. Helme,	G. Burtis Lee,	Wm. H. Greene,

Arts and Manufactures.	*Meteorology.*	*Meetings.*
Wm. B. Levan,	F. B. Maury,	Robt. B. Haines, Jr.,
Alfred Mellor,	Isaac Norris, Jr.,	Henry R. Heyl,
Henry Pemberton,	Hector Orr,	Washington Jones,
Wm. Volmer,	M. B. Snyder,	G. H. Perkins,
John J. Weaver.	Wm. H. Wahl.	E. Alex. Scott.

The following were announced as constituting the Special Committee on new building: WM. P. TATHAM, WM. SELLERS, J. VAUGHAN MERRICK, CHAS. BULLOCK, ISAAC NORRIS, JR., JNO. J. WEAVER, and CHAS. H. BANES.

Adjourned.

WM. H. WAHL, *Secretary.*

At the Annual Meeting, held Wednesday, January 20, 1886, the following reports were presented and accepted:

REPORT OF THE COMMITTEE ON LIBRARY FOR THE YEAR 1885.

WM. P. TATHAM, *President.*

SIR:—The Committee on the Library respectfully report that during the past year there have been added to the Library—

	Bound.	*Unbound.*	*Pamphlets.*	*Maps.*
Books purchased—volumes, . . .	224	34	92	. .
" " from B. H. Moore fund,	93	. . .	. . .	. .
" presented, ...	879	613	2,716	24
" purchased for Memorial Library,	17	1	3	. .
" donated to Memorial Library, .	5	20	17	. .
Exchanges bound, ...	452	. . .	. . .	. .
Books, other than Exchanges bound, .	128	. . .	. . .	. .
" rebound, ...	2	. . .	. . .	. .
	1,800	668	2,828	24

Making a total of . . . . . 5,296 volumes.

To which are to be added the volumes presented by Mrs. WM. B. ROGERS, from the library of the late Prof. ROBERT E. ROGERS, ... 883 "

And the volumes taken from the pamphlet collection and added to the Library, ... 97 "

Total additions during the year 1885, . . . 6,276 volumes.

Making the total number of volumes bound and unbound in the Library 24,240, exclusive of pamphlets, an increase of 8,861 volumes in the past five years.

The large amount of valuable pamphlets which has accumulated demanded an assorting and classifying of them, with an index which would make them available for reference—this work has been in progress during the past year, and 3,299 pamphlets have been so arranged; the work is still in progress.

THE EXCHANGES for the JOURNAL OF THE INSTITUTE number 331.

DUPLICATES.—A printed catalogue has been sent to the prominent Libraries of the United States with the view of effecting an exchange. During the year 114 volumes and pamphlets have been received in exchange.

SERIAL PUBLICATIONS.—A number of important works of this class have been completed, and the committee are endeavoring to fill up the deficiencies in important works

STATE PUBLICATIONS.—With the view of obtaining the official publications of the different States, correspondence has been opened, proposing to exchange the JOURNAL OF THE INSTITUTE for such publications, and favorable responses have been received from a number of States.

The increase of the Library has made it necessary to devise expedients for the relief of its crowded shelves. Many books which are least consulted have been removed to the model room, and shelving has been erected in part of the drawing room to relieve the pressure for space.

A new table for the Librarian, with conveniences for arranging and keeping the card catalogue, has been placed in the library during the past year.

CHAS. BULLOCK,
Chairman of Committee on the Library.

PHILADELPHIA, January 20, 1886.

REPORT OF THE ELECTRICAL SECTION FOR THE YEAR 1885.

WM. P. TATHAM, *President.*

SIR:—I have the honor to report that the Electrical Section of the FRANKLIN INSTITUTE has completed its second year with a considerable increase of membership, and an increase in attendance, which augurs well for the future.

The Treasurer reports, after paying all expenses, a balance in hand, January 15, 1886, of $123.14—not enough to enable us to purchase any instruments, but showing, nevertheless, careful and economical management.

The Secretary reports as follows:

During the past year, ten (10) names have been added to our list of members. We have lost one worthy member in the death of Mr. John W. Nystrom. Our membership at the close of 1884 was thirty-one (31) and, making the corrections to correspond with the above, would bring our *active* list up to forty (40) at the close of 1885. There is one honorary member, who was elected the past year. In addition to these, there are now three names before the Nominating Committee, to be acted upon at our next stated meeting.

Regular stated meetings were held once a month, excepting during July and August. One adjourned meeting was held December 14th, on account of Prof. Dolbear's lecture on "Telephone Systems," occurring on the night of the regular meeting, also one on January 5, 1886.

The average attendance has been 9·9. The largest number present at any one time was sixteen; the least, six. The attendance at the first adjourned meeting was eight; at the second, ten. Several visitors were present from time to time.

Ten (10) special committees were appointed during the year and one continued from the previous year—the Parkhurst Battery Committee.

Of these, five (5) were appointed to investigate subjects referred to the Section from the Committee on Science and the Arts. Three of these made the proper investigation, the reports were accepted by the Section and handed to the Committee on Science and the Arts, and duplicate copies placed on file in the archives. The subjects of these reports were:

Mr. W. B. Cooper's Thermo-magnetic Motor;

Mr. Wm. Walter's System of Underground Conduits;

Mr. Lucius J. Phelps' Induction Telegraph System as Applied to Moving Railway Trains.

Two are still under consideration, namely:

The Parkhurst Battery;

Mr. Van Gestel's Combined Arc and Incandes[illegible] amp.

Of the other special committees, those appointed to examine—

Mr. Murray Bacon's automatic signaling apparatus between the pilot and engineer of steam vessels; to report upon the advisability of the Section giving a course of lectures; and to

Revise the By-Laws,—presented reports which were accepted and filed.

The Committee on Instruments was made a standing committee, and the committees to—

Review the current electrical journals,—and to

Report on increasing the scope of the Section, have been continued.

There were brought before the meetings, from time to time, for the inspection of the members:

The Edgerton Motor;

Some experimental apparatus, illustrating the principles of the Cooper Thermo-Magnetic Motor;

Model of a section of Walter's Underground Conduit;

Photographs of flashes of lightning;

Photograph showing the separation of the carbons in a telephone transmitter (believed to be the first time on record);

The original seal of the first magnetic telegraph company;

And the Diehl Motor.

Mr. W. W. Griscom read a paper before one of the meetings on the methods of testing the efficiency of motors. The committee appointed to review the electrical journals presented numerous interesting notes from the home and foreign periodicals, and several interesting discussions have taken place at different times.

A very valuable donation was recently presented to the Section by the members of the family of the late Jos. Sailer, consisting of two printed and bound volumes of the minutes and transactions of the first magnetic telegraph company, from the time of its organization, May 15, 1845, down to 1859, when it amalgamated with the American Telegraph Company.

The historic value of this gift can scarcely be estimated, as the records contain a minute and exact account of all the difficulties that had to be overcome before the telegraph reached even the practical working standpoint it had attained twenty-seven years ago. In connection with this, Mr. Joseph Sailer, Jr., very kindly presented the original seal of the company to the Section as a valuable relic of the earlier days of telegraphy. Suitable letters were drawn up and forwarded to the donors, expressing the thanks of the Section for these valued gifts.

In retrospect, the opinion of your Secretary is, that the year just closed was one of marked advance for the Electrical Section, and our present condition warrants the prediction that a bright future is before us in the year just opening.

The Committee on Increasing the Scope of the Electrical Section report as follows:

ELECTRICAL SECTION, FRANKLIN INSTITUTE.

PHILADELPHIA, January 5, 1886.

To the President and Members of the Electrical Section:

Your committee to whom was referred the question of devising means to develop the usefulness of the Section and to secure a more regular attendance of its members, beg leave to make the following report:

The committee have held several meetings, and have discussed the subject in all its bearings. The active membership of the Section is forty-two, but while the average attendance at the meetings is fair, there is too small a proportion of members regularly present to secure the best results.

The first requirement of a successful organization is that there shall be a sufficient number who can be positively relied upon to attend all the meetings and enter heartily into the work of the Section. There is undoubtedly more than enough members willing to form such a nucleus if the meetings can be made sufficiently interesting to draw them together. This is proven by the fact that whenever anything of special interest is announced the attendance is large and the meeting is a profitable one.

What then can be done to improve the character of the meetings? The committee have received many valuable suggestions from the other members, which have been carefully considered; among them, that of bringing before the meetings systematically the latest information culled from American and foreign electrical journals, which has already been acted upon by the Section; that we shall arrange to have lectures from eminent electricians delivered before the Section; and third, that the several members of the Section shall prepare and read at the stated meetings monographs on electrical subjects; all of which are recommended by the committee for favorable action.

This, however, will not meet the case. It has long been recognized that the Section is not properly equipped for doing the work which is expected of it. It is true that it has made several reports, which have been very satisfactory to the INSTITUTE, on important electrical inventions which have come before the INSTITUTE for investigation, but it has been unable to properly investigate many of the subjects which have been referred to it by the Committee on Science and the Arts, because it has had no facilities at its command to make the necessary tests or experiments to prove or disprove the claims of the inventor.

What is needed is a small laboratory, with a comparatively few instruments to start with; and this laboratory and its equipment should be under the exclusive control of the Section. The opportunity which it would afford for original investigation, and for conveniently demonstrating the truth or falsity of newly-advanced theories, etc., would go far to enlist the active coöperation of many members who at present feel this lack of facilities, and who could not otherwise be interested in the work of the Section.

Can the INSTITUTE supply our necessities in this respect, or can individuals be found who will put the Section on its feet? In answer to this, it may be stated that some of the necessary instruments were purchased by the INSTITUTE for the use of the Section just at the close of the Electrical Exhibition, over a year ago. They comprise one Wiedermann galvanometer, one set of Hartmann resistance coils, one telescope and scale for reading the galvanometer, and one standard ohm. These instruments have not yet come into the possession of the Section. They have been doing good work in the hands of the experts employed by the INSTITUTE to conduct the tests on incandescent lamps and on dynamos, the admirable reports of which have been recently published. It is important that the Section should come into possession of these or similar instruments whenever it has a proper place to mount them.

Can the INSTITUTE give us a room for a laboratory? This matter has been carefully looked into. The committee believe that, if possible, this laboratory should be within, or near, the INSTITUTE building and its archives. A suitable room should be upon the ground floor, and it has been suggested that underneath the occupied portions of the building there is a large basement which, many years ago, was divided into rooms and used for drawing schools, etc., but which is now occupied for storage only. Possibly accommodations could be secured in that basement, either in one of the unused rooms on the street, or further back; and it is recommended by the committee that application be made to the Board of Managers not only for suitable quarters for a laboratory, and for the archives of the Section, but also for the custody of the instruments before referred to.

The suggestion has been made that it would be proper and advisable to use the funds in the treasury of the Section for the purchase of instruments, and that we might, perhaps, be able to secure contributions for this purpose. Certain members of the Section have offered to construct some of the necessary instruments, and Professor Anthony, of Cornell University, has kindly agreed to graduate them at a nominal charge.

A nucleus of earnest workers and a little encouragement and aid from the parent organization would soon make the Section a valuable adjunct to the INSTITUTE; there would be plenty of work for it to do and there would be no lack of interest in the work. The times seem to be propitious for the establishing of a good, strong electrical organization in this city, either under the auspices of the INSTITUTE or independent of it. Electrical science is now making rapid growth, and it would seem eminently proper that the INSTITUTE which, in times past, has been prominently identified with that science should not now take a secondary position.

The recommendations of the committee are briefly,—to bring before the meeting recent electrical news; to arrange at the proper time for lectures; to prepare monographs on electrical subjects; and to memorialize the Board of Managers for quarters and instruments.

Respectfully submitted,

E. ALEX. SCOTT, *Chairman*,
JAMES WILSON,
CHAS. H. RICHARDSON,
R. B. HAINES, JR.,
A. B. BURK.

In conclusion, we have to acknowledge the many and important advantages which the FRANKLIN INSTITUTE confers on its Sections, with the hope that it may see fit to grant the Electrical Section the further assistance which its growing usefulness would appear to warrant.

W. W. GRISCOM, *President.*

REPORT OF THE CHEMICAL SECTION FOR THE YEAR 1885.

WM. P. TATHAM, *President.*

SIR:—The Chemical Section of the INSTITUTE respectfully reports that during 1885 the following officers served:

President.—PROF. S. P. SADTLER.

Vice-Presidents.— { DR. ISAAC NORRIS. / MR. G. G. BROWNING.

Treasurer.—MR. CHAS. BULLOCK.

Conservator.—DR. WM. H. WAHL.

Secretary.—HENRY PEMBERTON, JR.

The membership at the end of the year was fifty; four members having been elected, and one having resigned during the year.

The following subjects were brought before the meetings and discussed:

Analyses of water from near Reading, Pa., by Prof. Luthy.

Analyses of Extracts of Licorice, with samples, by Prof. Sadtler.

Beautiful specimens of anthracene, anthraquinone, alizarine, carbon tetrabromide, and phosphorous subsulphide, by Dr. H. W. Jayne.

Manufacture of beet root sugar, with methods of removing foreign bodies, by Prof. Luthy.

The Bower-Barff process of giving iron a non-oxidizable coating, by Prof. Sadtler.

Use of blast furnace slag for paving purposes, and for manufacture of "slag-wool," by Prof. Sadtler.

A new apparatus for accurately determining the volume of gases, invented and described by Dr. Keiser.

Process for extracting oil and albuminoid matter from corn, patented and described by Dr. F. V. Greene. This process was referred by the Committee on Science and the Arts to the Chemical Section, was examined and reported upon by a sub-committee, and transmitted by it to the Committee on Science and the Arts.

In addition to the above, a variety of other matters received an informal and general discussion at different times.

The Section subscribes to a number of foreign chemical journals, which are bound by the INSTITUTE, and kept upon its shelves.

Regular meetings are held on the second Tuesday of each month, except during summer. The members have shown much interest in the meetings, and the attendance has been good; particularly so during the latter half of the year.

Respectfully,

HENRY PEMBERTON, JR., *Secretary.*

PHILADELPHIA, January 12, 1886.

REPORT OF PHONETIC SHORTHAND SECTION FOR THE YEAR 1885.

W. P. TATHAM, *President.*

SIR:—I beg leave to report that the Phonetic Shorthand Section, through its Executive Committee, continued the organization of the practice class of the Section during the first six months of the year. The meetings of this class were held one each week with an attendance of from twelve to twenty pupils. Last spring a very interesting lecture was delivered under the auspices of the Section, by Mr. John Sartain, on "Ancient Art," which was published in the JOURNAL OF THE INSTITUTE.

Since the organization of the Section much has been done through its influence to secure a uniformity in shorthand writing in this city and in simplifying the methods of teaching it. Many of the pupils taught in its classes are filling important clerical positions in some of our largest business houses, and the demand for really good shorthand clerks is now greater than the supply.

The teaching of phonetic shorthand according to the primary method has been introduced into the Northern Home for Friendless Children and the Soldiers' Orphans' Institute, through the influence, direct and indirect, of this Section. The Section was directly instrumental in introducing the teaching of shorthand classes in Girard College, the New Century Guild for Working Women, and the Women's Christian Association.

Shorthand is not yet taught in the Public Schools of Philadelphia, but many teachers in public schools have received instruction in the art in accordance with the resolution of the Committee of Instruction of the FRANKLIN INSTITUTE. Very Respectfully, E. ALEX. SCOTT,

Prest. Phon. Shorthand Section.

PHILADELPHIA, December 16, 1885.

BOOK NOTICE.

SPECIALISTS' SERIES VOL. I. MAGNETO- AND DYNAMO-ELECTRIC MACHINES: with a Description of Electric Accumulators. From the German of Glaser de Cew by F. Krohn, edited by Paget Higgs, LL. D., D. Sc. London: Symons & Co. New York: D. Van Nostrand.

The author presents a well arranged and complete treatise upon the subject indicated in the title. A historical outline of the development of the dynamo-electric generator is followed by a description in detail with numerous illustrations of the various constructions and applications of both alternating and direct current machines, with a comparison of their relative advantages and disadvantages under varying conditions.

One chapter is specially devoted to electrical accumulators.

The theoretical treatment is very complete, including the latest theories advanced by the highest authorities.

The construction of electric generators as well as their application to lighting purposes, etc., receives able treatment, including the latest obtainable data.

Special attention is directed to the description of instruments for electrical measurements. H. B.

LIST OF BOOKS

ADDED TO THE LIBRARY FROM MARCH 1, 1885.

Cambridge, Mass. Annual Report of Board of Health. 1884.
Presented by the Board.

Canada. Annual Report of Minister of Railways and Canals for Fiscal Year ending June 30, 1883. Presented by the Minister.

Canada, Map of Dominion of. 1882.
Presented by the Minister of Railways and Canals.

Canada, Railways of. Maps to Accompany Annual Reports on Railway Statistics. 1884.

Canada, Reports of Railways Statistics of. For 1875–76 and 1877–78 to 1883–84. Ottawa, 1877–85. Presented by the Minister.

Canadian Institute. Proceedings. Vol. 1. Toronto.

Central Railroad and Banking Company of Georgia. Thirty-seventh, Fortieth to Forty-ninth Annual Reports, 1872–84.
Presented by the Company.

Ceylon. The Patent Law, Practice and Forms. New York, 1885.
Presented by Richards & Co.

Chadwick, F. E. Report on the Training Systems for the Navy and Mercantile Marine of England, etc. Washington, 1880.
Presented by Prof J. R. Soley, Library Navy Department, U. S.

Chance, Dr. H. M. Relative Value of Coals to the Consumer. 1885.
Presented by the American Institute of Mining Engineers.

Chase, P. E. Further Experiments in Weather Forecast.

Chemical News. Vols. 49–50. London, 1884.

Chemical Society. Journal. Vols. 43–46. London, 1883–84.

Cherokee Nation, Laws of. Passed during the Years 1839–67. St. Louis, 1868.

Cheshire Railroad Company. Thirty-ninth and Fortieth Annual Reports of the Directors. 1884–85. Presented by the Company.

Chicago Board of Public Works. Third Annual Report for Fiscal Year ending March, 1864. Chicago.

Chicago, Burlington and Quincy Railroad Company. Thirty-first Annual Report of Board of Directors, 1884. Cambridge.
Presented by the Company.

Chicago Historical Society. Early Society in Southern Illinois. By R. W. Patterson, Chicago, 1881; and, Father Marquette, at Mackinaw and Chicago. By H. H. Hurlbut. Chicago, 1878.
Presented by the Society.

Chism, R. E. Mining Code of Mexico. Transactions of American Institute of Mining Engineers. 1885. Presented by the Institute.

Cincinnati. Annual Reports of the Health Department to Councils, 1884.
Presented by C. W. Rowland, Health Officer.

Cincinnati Industrial Exposition. Twelfth Report of the Board of Commissioners. 1884. Cincinnati. Presented by the Secretary.

Cincinnati, Ohio. Annual Reports of Water Department for 1883–84. Presented by the Department.

Cincinnati. Public Library. Bulletins of Books added in 1878–82 and 1884. Cincinnati Finding List. 1882–84. Presented by the Librarian.

Cincinnati Society of Natural History. Journal. No. 1, Vol. 8. Cincinnati, 1885. Presented by the Society.

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